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SATURN S-IVB-206 STAGE ACCEPTANCE FIRING REPORT

DOUGLAS REPORT SM-47472
OCTOBER 1966

MISSILE & SPACE SYSTEMS DIVISION
DOUGLAS AIRCRAFT COMPANY, INC.
SANTA MONICA/CALIFORNIA

DOUGLAS

SATURN S-IVB-206 STAGE ACCEPTANCE FIRING REPORT

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PREPARED BY:
DOUGLAS AIRCRAFT COMPANY, INC.
SATURN S-IVB TEST PLANNING
AND EVALUATION COMMITTEE

PREPARED FOR:
NATIONAL AERONAUTICS AND
SPACE ADMINISTRATION
UNDER NASA CONTRACT NAS7-101

A P O'Neal

APPROVED BY: A. P. O'NEAL
DIRECTOR, SATURN DEVELOPMENT ENGINEERING

DOUGLAS MISSILE & SPACE SYSTEMS DIVISION
SPACE SYSTEMS CENTER — HUNTINGTON BEACH, CALIFORNIA

ABSTRACT

This report presents an evaluation of the Saturn S-IVB-206 stage acceptance firing that was conducted at the Sacramento Test Center on 19 August 1966. An engine performance verification firing was accomplished on 14 September 1966. Included in this report are stage and ground support equipment deviations associated with the acceptance firing configuration.

The acceptance firing test program was conducted under National Aeronautics and Space Administration Contract NAS7-101, and established the acceptance criteria for buyoff of the stage.

DESCRIPTORS

Saturn S-IVB-206 Stage

Saturn S-IVB/IB Stage

Saturn S-IVB-206 Stage Test Evaluation

J-2 Engine

Beta Complex

Engine Performance Verification Firing

Saturn S-IVB-206 Acceptance Firing

Saturn S-IVB-206 Stage Test Configuration

Sacramento Test Center

Countdown Operations

Sequence of Events

PREFACE

The purpose of this report is to document the evaluation of the Saturn S-IVB-206 stage acceptance firing as performed by Douglas personnel at the Sacramento Test Center.

This report, prepared under National Aeronautics and Space Administration Contract NAS7-101, is issued in accordance with the contractual requirements of Douglas Report No. SM-41410, Data Submittal Document, Saturn S-IVB System, dated 1 December 1965.

This report evaluates stage test objectives, instrumentation, and configuration deviations of the stage, test facility, and ground support equipment.

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1. INTRODUCTION

1.1 General

This report was prepared at the Douglas Huntington Beach Space Systems Center by the Saturn S-IVB Test Planning and Evaluation (TP&E) Committee for the National Aeronautics and Space Administration under Contract NAS7-101.

Activities connected with the Saturn S-IVB-206 stage included prefiring checkout and the acceptance firing. Checkout started at the subsystem level and progressed to completion with the integrated systems test and the simulated static firing. The information contained in the following sections documents and evaluates all events and test results of the acceptance firing which was completed on 19 August 1966. A 70-sec engine performance verification firing on 14 September 1966 was required when the LOX turbopump was replaced after the acceptance firing. The tests were performed at the Complex Beta Test Stand III, Sacramento Test Center (STC).

1.2 Background

The S-IVB-206 stage was assembled at the Huntington Beach Space Systems Center. A checkout was performed in the vertical checkout laboratory (VCL) prior to shipping the stage to STC. The stage was installed on the test stand on 30 June 1966 and was ready for acceptance firing on 16 August 1966.

The APS modules were shipped to the manufacturing and assembly (M&A) building at STC for leak and functional checks. No confidence firings of these modules were scheduled.

Table 1-1 lists the milestones of the Saturn S-IVB-206 stage events and dates of completion.

1.3 Objectives

All test objectives outlined in Douglas Report No. SM-47456A, Saturn S-IVB-206 Stage Acceptance Firing Test Plan, dated May 1966 and revised August 1966 were successfully completed.

Stage acceptance objectives which provided maximum system performance evaluation were as follows:

a. Countdown control and operation capability verification

b. *J-2 engine system performance verification

c. Oxidizer system performance verification

d. Fuel system performance verification

e. Pneumatic control system performance verification

f. Propellant utilization system performance verification

g. Stage data acquisition system performance verification

h. Stage electrical control and power system performance verification

i. Hydraulic system and J-2 engine gimbal control performance verification

j. Structural integrity verification

k. APS stage interface compatibility verification.

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* This objective was verified during the 70-sec engine performance verification firing.

TABLE 1-1
MILESTONES, SATURN S-IVB-206 STAGE

EVENT	COMPLETION DATE
Tank Assembly	15 October 1965
Proof Test	8 November 1965
Insulation and Bonding	14 January 1966
Stage Checkout and Join J-2 Engine	5 April 1966
Systems Checkout	27 May 1966
Ship to STC	30 June 1966
Stage Installed on Test Stand	8 July 1966
Ready for Acceptance Firing	16 August 1966
Acceptance Firing	19 August 1966
Engine Performance Verification Firing	14 September 1966
Stage Received at VCL	4 October 1966
All Systems Test	17 October 1966
Ready to Ship to KSC (DD 250 Signed)	31 October 1966

2. SUMMARY

The S-IVB-206 stage was acceptance fired on 19 August 1966 at Complex Beta, Test Stand III, Sacramento Test Center. The countdown was designated as CD 614070. The mainstage firing duration was 433.7 sec; engine cutoff was initiated by the observer due to LH2 pump inlet conditions.

A routine postfiring LOX turbine swab check revealed numerous metallic particles in the turbopump. The turbopump was replaced, necessitating a short-duration J-2 engine refiring to calibrate the new pump to the J-2 engine.

The engine performance verification firing was successfully accomplished on 14 September 1966. The countdown was designated as CD 614072. The mainstage duration was 66.6 sec and engine cutoff was initiated from the test operator's console as planned.

2.1 Countdown Operations

Countdown 614069 was terminated after one day in order to install vibration measurements on the LOX low pressure feed duct. Countdown 614070 was then initiated and proceeded smoothly to a successful acceptance firing on 19 August 1966. All objectives of the acceptance firing test plan were satisfied.

Two anomalies were experienced during this countdown.

a. During Integrated System Test, (IST) a lead gas ignitor malfunctioned and was replaced.

b. During LOX loading, No. 3 LOX level depletion sensor cycled several times. After a few minutes, the sensor indicated wet and operated normally throughout the rest of the countdown.

Countdown 614072 was uneventful and proceeded smoothly to a successful short-duration verification firing on 14 September 1966. No anomalies were experienced during the countdown, and the J-2 engine performance verification objective was satisfied.

2.2 J-2 Engine System

The J-2 engine (S/N 2046) performed satisfactorily throughout the acceptance firing except for the LOX turbopump malfunction. The LOX turbopump was replaced and the engine performance during the short duration verification firing showed satisfactory engine operation with the new LOX turbopump.

The J-2 engine performance was reconstructed from engine start to engine cutoff for both the stage acceptance firing and the engine performance verification firing.

2.3 Oxidizer System

The oxidizer system functioned adequately, supplying LOX to the engine pump inlet within the specified operating limits. The available net positive suction head (NPSH) at the LOX pump inlet exceeded the manufacturer's minimum requirement at all times.

2.4 Fuel System

The fuel system performed as designed and supplied LH2 to the engine within the limits defined in the engine specification. Evaluation indicated pressurization, chilldown, and supply functions were nominal in all respects.

2.5 Pneumatic Control and Purge System

The pneumatic control and purge system performed satisfactorily throughout the acceptance firing. The helium supply to the system was adequate for both pneumatic valve control and purging; the regulated pressure was maintained within acceptable limits and all components functioned normally.

2.6 Propellant Utilization (PU) System

The PU system accomplished all the design objectives as listed in DAC Report No. SM-47456, Saturn S-IVB-206 Stage Acceptance Firing Test Plan.

2.7 Data Acquisition System

The data acquisition system performed satisfactorily throughout the acceptance firing and the engine performance verification firing. One hundred and seventy-six measurements were active of which six failed during the acceptance firing and eight failed during the engine verification. This resulted in a measurement efficiency of 97 percent for the acceptance firing and 95.5 percent for the engine verification.

2.8 Electrical Power and Control Systems

The electrical power and control systems performed satisfactorily throughout the acceptance firing.

2.9 Hydraulic System

The hydraulic system operated properly supplying pressurized fluid to the servo-actuators. All specified test objectives were achieved and all system variables operated within design limits.

2.10 Flight Control System

The dynamic response of the hydraulic servo-thrust vector control system was measured while the J-2 engine was gimbaled during the acceptance firing. The performance of the pitch and yaw hydraulic servo control systems was found to be acceptable.

2.11 Structural System

Structural integrity of the stage was maintained for the vibration, temperature, and thrust load conditions of both the acceptance firing and the engine performance verification firing. Minor structural debonding of supports in the tunnel areas occurred. Also, the aft skirt purge membrane separated from the LOX dome during both firings and minor unbond of the LH2 tank fiberglas cloth liner was detected after the firings.

2.12 Thermoconditioning and Purge System

The thermoconditioning and purge system functioned properly during both firings. All system temperatures and flowrates were maintained within design limits.

2.13 Acoustic and Vibration Environment

A total of 14 vibration measurements were monitored during the acceptance and engine verification firings. Eleven measurements provided usable data; two measurements provided data usable only for trend purposes, and one measurement provided no data. No acoustic measurements were monitored.

There was no evidence of any vibration problems during either firing. There was an anomaly in the LOX feedline data during the acceptance firing; however, the instrumentation systems were changed and good data were obtained during the engine verification firing.

2.14 Reliability and Human Engineering

All functional failures of Flight Critical Items and Ground Support Equipment/Special Attention Items were investigated by Reliability Engineering. A Human Engineering evaluation has been conducted in support of the acceptance firing and recommendations for changes to the operation have been taken into consideration.

3. TEST CONFIGURATION

This section describes the stage and ground support equipment (GSE) deviations and modifications from the flight configuration affecting the acceptance firing. Additional details of specific system modifications are discussed in appropriate sections of this report. Details of the S-IVB-206 stage configurations are presented in DAC Report No. 1B62934, S-IVB-206 Stage End-Item Test Plan.

Figure 3-1 is a schematic of the S-IVB-206 stage propulsion system and shows the telemetry instrumentation transducer locations from which the test data were obtained. The functional components are listed in table 3-1. Hardwire measurements are noted in the appropriate subsystem schematics included in this report. The propulsion system orifice characteristics and pressure switch settings are presented in tables 3-2 and 3-3. J-2 engine S/N 2046 was installed.

The propulsion GSE (figure 3-2) consisted of pneumatic consoles "A" and "B", two propellant fill and replenishing control sleds, a vacuum system console, and a gas heat exchanger.

3.1 Configuration Deviations

Configuration deviations required for the acceptance firing are discussed in DAC Report No. SM 47456A, Saturn S-IVB-206 Stage Acceptance Firing Test Plan. Significant configuration changes to the stage and GSE are discussed in the following paragraphs.

3.1.1 Engine Restrainers

J-2 engine unlatch restrainer link kit. Model DSV-4B-618, was installed to restrain the engine during start transient side loads.

3.1.2 Quick Disconnects

The stage-mounted portions of the pneumatic and propellant umbilical quick disconnects were replaced by hardlines.

3.1.3 Engine Diffuser

A water-cooled converging diffuser, Model DSV-4B-639 engine bell extension service unit, was installed to the engine thrust chamber exit to reduce the nozzle area ratio and the probability of jet-separation-induced side loads.

3.1.4 Auxiliary Pressurization

An auxiliary propellant tank pressurization system was installed and was supplied from a GSE ambient helium source.

3.1.5 Propellant Fast Fill Sensors

Propellant loading fast fill sensors were installed on the instrumentation probes but were used in the indicating mode only.

3.1.6 Stage Vent and Bleed System

All stage propellant vent and bleed systems were connected to the facility vent system.

3.1.7 Forward Skirt Cooling

The forward skirt thermoconditioning system coolant was supplied by a Model DSV-4B-359 servicer, rather than the flight source in the instrument unit.

3.1.8 Aft Interstage

The stage was mounted on a Model DSV-4B-540 dummy aft interstage instead of the flight interstage.

3.1.9 Fire Detection System

A resistance wire fire detection system was installed in critical areas of the stage, GSE, and facilities.

3.1.10 GH2 Detectors

GH2 leak detectors were installed in critical areas of the stage, GSE, and facilities.

3.1.11 Blast Detectors

Blast detectors were installed in the test area to monitor an overpressure range of 0 to 25 psi overpressure.

3.1.12 Auxiliary Propulsion System (APS)

The flight APS modules were not installed. Instead, the Model 188B APS Simulator was connected to position 1 and 2 to receive commands and close the control circuitry.

3.1.13 Telemetry System

Those telemetry channels that were left blank when various parameters were disconnected to be recorded by other means were either left open or were simulated.

3.1.14 Hardwire Transducers

The Marshall Space FLight Center firing measurement (Scope Change 1195A) program hardwire transducers were installed for the acceptance firing. These transducers will be removed before the stage leaves STC.

3.1.15 Forward Stage/Instrumentation Unit (IU) Interface

The IU was not available at the Sacramento Test Center; therefore, the IU and S-IB electrical interfaces were simulated by GSE.

3.1.16 Electrical Umbilicals

The electrical umbilicals remained connected throughout the acceptance firing.

3.1.17 Instrumentation System

The stage data acquisition system is defined in drawing 1B43559, Instrumentation Program and Components List, Saturn S-IVB-206, except as called out in section 11.

TABLE 3-1 (Sheet 1 of 5)
S-IVB-206 STAGE HARDWARE LIST

ITEM NO.*	PART NO.	NAME
1	7851861-1	Disconnect, LH2 tank pressurization
2	1B65673-1	Valve, check, LH2 tank prepressurization line
3	1B53817-505	Valve, hand, 3-way, LH2 and LOX fill and drain valves, nonpropulsive vent and LH2 chilldown valve purge line
4	1B51361-1	Valve, check, LH2 fill and drain valve and nonpropulsive vent purge line
5	1B53817-505	Valve, hand, 3-way, LOX vent and relief valve purge line
6	7851823-503	Disconnect, ambient, helium fill
7	1B63206-1	Orifice, ambient helium fill
8	1B51361-1	Valve, check, control helium fill
9	1A57350-505	Module, control helium fill
10	1A49963-1	Sphere, control helium, 905 sci
11	1A48848-505	Disconnect, LH2 tank vent
12	1B66932-501	Disconnect, LH2 fill and drain
13	1B40622-505	Orifice, LH2 fill and drain valve purge line
14	1B65292-501	Module, actuation control, LH2 fill and drain valve
15	1B41065-1	Disconnect, common bulkhead vacuum system
16	1A48240-505	Valve, LH2 fill and drain
17	1B66932-501	Disconnect, LOX fill and drain
18	1B51361-1	Valve, check, LOX fill and drain valve purge line
19	1B40622-505	Orifice, LOX fill and drain valve purge line
20	1A48240-505	Valve, LOX fill and drain
21	1B65292-501	Module, actuation control, LOX fill and drain valve
22	1A57781-501	Module, cold helium fill

* Indicates location in figures 3-1 and 3-2.
P/U - Pickup
D/O - Dropout

TABLE 3-1 (Sheet 2 of 5)
S-IVB-206 STAGE HARDWARE LIST

ITEM NO.*	PART NO.	NAME
23	1B40824-503	Valve, check, cold helium fill line
24	1B42290-503	Module, LOX tank pressure control
25	7851844-501	Disconnect, cold helium fill and LOX tank prepressurization
26	1B40824-503	Valve, check, cold helium fill and LOX prepressurization line
27	1A49991-1	Plenum, LOX tank pressurization, 250 sci
28	7851830-517	Switch, pressure, LOX tank pressurization regulator backup P/U 465 +20 -15 psia, D/O 350 +20 -15 psia
29	1B63047-509	Orifice, LOX tank pressurization, heat exchanger primary
30	1B63047-509	Orifice, LOX tank pressurization, heat exchanger bypass
31	1A49958-517	Disconnect, thrust chamber jacket purge and chilldown
32	1B51361-1	Valve, check, thrust chamber jacket purge line
33	1B43657-11	Module, pneumatic power control
34	1A48857-1	Plenum, control helium, 100 sci
35	1B55200-505	Module, LH2 tank pressure control
36	1B51361-1	Valve, check, LH2 nonpropulsive vent purge line
37	1B40622-501	Orifice, LH2 nonpropulsive vent purge line
38	1B59265-1	Orifice, nonpropulsive vent
39	1B59265-1	Orifice, nonpropulsive vent
40	7851860-541	Switch, pressure, LH2 flight control, P/U 29.5 psia, D/O 26.5 psia

* Indicates location in figures 3-1 and 3-2.
P/U - Pickup
D/O - Dropout

TABLE 3-1 (Sheet 3 of 5)
S-IVB-206 STAGE HARDWARE LIST

ITEM NO.*	PART NO.	NAME
41	7851860-537	Switch, pressure, LH2 prepressurization and ground fill, P/U 34 psia max, D/O 31 psia min
42	1A67005-507	Switch, pressure, LH2 tank orbital vent initiation, P/U 35.5 ±0.75 psia max, D/O 31 psia min
43	Deleted	
44	1B53817-1	Valve, 3-way, LH2 tank pressure switch shutoff
45	1A49988-1	Valve, directional control, LH2 vent
46	1A49591-527	Valve, relief, LH2 tank, crack 40 psia max, reseat 37 psia min
47	1A48257-509	Valve, vent and relief, LH2 tank, crack 39 psia max, reseat 37 psia min
48	1A48851-1	Sphere, storage cold helium (6 each)
49	1B58100	Probe, LH2 temperature sensor
50	1A48431-501	Probe, LH2 mass sensor
51	1A69405	Probe, LOX temperature sensor
52	1A48430-507	Probe, LOX mass sensor
53	1A49421-501	Pump, LH2 childown
54	1A48854-1	Orifice, LOX childown pump purge line
55	1A58347-505	Module, LOX childown pump purge
56	1A49423-505	Pump, LOX childown
57	1A49964-501	Valve, check, LOX childown return line
58	7851847-535	Switch, pressure, LOX childown pump purge regulator backup P/U 53 psia max, D/O 49 psia min
59	114-109	Valve, relief, LOX childown pump motor, container, crack and reseat 65 psia to 85 psia

* Indicates location in figures 3-1 and 3-2.
P/U - Pickup
D/O - Dropout

TABLE 3-1 (Sheet 4 of 5)
S-IVB-206 STAGE HARDWARE LIST

ITEM NO.*	PART NO.	NAME
60	1A67913-1	Valve, vent, LOX chilldown pump motor container
61	1A49965-521	Valve, shutoff, LOX chilldown line
62	1A89104-509	Flowmeter, LOX chilldown line
63	1A87749-1	Strainer, LOX chilldown pump discharge
64	1A49968-509	Prevalve, LOX
65	1B53817-505	Valve, 3-way, LOX tank pressure switch shutoff
66	Deleted	
67	1B65292-501	Module, actuation control, directional valve, LH2 vent
68	1B65292-501	Module, actuation control, LH2 vent and relief valve
69	7851847-533	Switch, LOX prepressurization, flight and ground fill control, P/U 40 psia max, D/O 37 psia min
70	1A49964-501	Valve, check, LH2 chilldown return line
71	1A49968-507	Prevalve, LH2
72	1A49965-519	Valve, shutoff, LH2 chilldown pump discharge
73	1B52985-501	Strainer, LH2 chilldown pump discharge
74	1B53920-503	Valve, check LH2 chilldown pump discharge
75	1A89104-507	Flowmeter, LH2 chilldown pump discharge
76	1B65292-501	Module, actuation control, prevalves and chilldown valves
77	1B40622-507	Orifice, LH2 chilldown shutoff valve purge line, 14 scfm
78	1B51361-1	Valve, check, LOX vent and relief valve purge line

* Indicates location in figures 3-1 and 3-2.
P/U - Pickup
D/O - Dropout

TABLE 3-1 (Sheet 5 of 5)
S-IVB-206 STAGE HARDWARE LIST

ITEM NO.*	PART NO.	NAME
79	Deleted	
80	1B63206-1	Orifice, flow, LOX vent and relief valve purge line
81	1A49590-513	Valve, relief, LOX tank, crack 45 psia, reseat 42 psia
82	1A48312-505	Valve, vent and relief, LOX tank, crack 44 psia, reseat 41 psia
83	1B65292-501	Module, actuation control, LOX vent and relief valve
84	1B56804-1	Module, engine purge control
85	1A67002-509	Switch, pressure, engine purge regulator backup, P/U 130 psia max, D/O 105 psia min
86	1A49958-521	Disconnect, engine start sphere vent and relief valve drain
87	1A49958-515	Disconnect, engine control helium sphere fill
88	1A49958-523	Disconnect, engine start sphere fill

* Indicates location in figures 3-1 and 3-2.
P/U - Pickup
D/O - Dropout

TABLE 3-2 (Sheet 1 of 2)
S-IVB-206 STAGE AND GSE ACCEPTANCE FIRING ORIFICES

ITEM* No.	DESCRIPTION	ORIFICE SIZE OR NOMINAL FLOWRATE	COEFFICIENT OF DISCHARGE	EFFECTIVE AREA ($in.^2$)
	Stage			
7	Ambient Helium Fill	65 scfm	--	Sintered
13	LH2 Fill and Drain Valve Purge	15 scim at 3,200 psid	--	Sintered
19	LOX Fill and Drain Valve Purge	15 scim at 3,200 psid	--	Sintered
29	LOX Tank Pressurization System Heat Exchanger Outlet	0.196 in. dia	0.87	0.0261
30	LOX Tank Pressurization System Heat Exchanger Bypass	0.169 in. dia	0.88	0.0198
35	LOX Tank Pressurization Module			
	Undercontrol	0.252 in. dia	0.86	0.0427
	Overcontrol	0.228 in. dia	0.86**	0.0778**
	Step	0.323 in. dia	0.82**	0.1416**
37	LH2 Tank Nonpropulsive Vent Purge	1 scfm at 3,200 psid	--	Sintered
38-39	LH2 Tank Nonpropulsive Vent(2)	2.180 in. dia	NC	--
54	LOX Chilldown Pump Purge Flow Control	37 scim at 475 psid	--	Sintered
55	LOX Chilldown Pump Purge Module	0.00166 lb/sec at 475 psig IN and 85 psig OUT	N/A	
77	LH2 Chilldown Valve Purge	65 scfm at 3,000 psid	--	Sintered
80	LOX Tank Vent and Relief Valve Purge	65 scfm at 3,000 psid	N/A	0.00043
84	Engine Pump Purge Module	0.00166 lb/sec at 475 psig IN and 85 psig OUT	--	0.00023
	Console A			
A9538	LH2 Tank Repressurization Supply	Union	--	--
A9537	Pressure Switch Checkout--High Pressure	0.032 in. dia	--	--
A9536	Pressure Switch Checkout--Low Pressure	1.2 scfm	--	Sintered

* Indicates location in figures 3-1 and 3-2.

** Discharge coefficient and effective area are calculated for overcontrol and step orifices in successive combination with the undercontrol orifice.

N/A Not available

TABLE 3-2 (Sheet 2 of 2)
S-IVB-206 STAGE AND GSE ACCEPTANCE FIRING ORIFICES

ITEM* NO.	DESCRIPTION	ORIFICE SIZE OR NOMINAL FLOWRATE	COEFFICIENT OF DISCHARGE	EFFECTIVE AREA (in.^{2})
A9535	LH2 Tank and Umbilical Purge Supply	0.260 in. dia	0.88	0.04675
--	All Console A Stage Bleeds	Variable	--	--
A9515	Pressure Actuated Valve and Mainstage Pressure Switch Supply	1.2 scfm	--	Sintered
A9533	LH2 System Checkout Supply	1.2 scfm	--	Sintered
A9534	LOX System Checkout Supply	5.0 scfm	--	Sintered
A9539	Console GN2 Inerting Supply	0.013 in. dia	--	--
A9526	J-Box Inerting Supply	0.013 in. dia	--	--
	Console B			
--	All Console B Stage Bleeds	Variable	--	--
A9529	LOX Tank and Umbilical Purge System	0.305	0.88	0.06450
--	Turbine Start Sphere Supply	Union	--	--
A9552	Turbine Start Sphere Supply Vent	0.081 in. dia	0.84	0.00433
A9528	Thrust Chamber Jacket Purge and Chilldown System	0.072 in. dia	0.86	0.00350
A9525	Engine Control Sphere Supply	0.125 in. dia	0.85	0.01040
--	LOX Tank Prepressurization Supply	0.096 in. dia	0.94	0.00680
A9527	LH2 Tank Prepressurization Supply	0.162 in. dia	0.80	0.01650
A9348	Console GN2 Inerting Supply	Manifold	--	--
A9540	J-Box Inerting Supply	0.013 in. dia	--	--
A9550	Engine Control Sphere Supply Vent	--	--	--

* Indicates location in figures 3-1 and 3-2.

TABLE 3-3
S-IVB-206 STAGE PRESSURE SWITCHES

PARAMETER	PART NO.	PRESSURE (psia)							
		SPECIFIED		PRETEST-RUN 2A		PRETEST-RUN 3A		POST-TEST	
		PICKUP	DROPOUT	PICKUP	DROPOUT	PICKUP	DROPOUT	PICKUP	DROPOUT
<u>LH2 TANK</u>									
Flight Control	7851860-541	30.0 max	26.5 min	28.9	26.8	28.8	26.5	29.3	26.9
Prepress and Ground Fill Vlv Control	7851860-537	34.5 max	30.5 min	33.4	31.4	33.4	31.3	33.9	31.9
<u>LOX TANK PRESSURIZATION SYSTEM</u>									
LOX Prepress, Flt Control and Ground Fill Vlv Control	7851847-533	41 max	36.5 min	40.3	37.7	40.2	37.6	40.4	37.7
LOX Tank Regulator Backup	7851830-517	467.5 ±23.5	352.5 ±23.5	460.4	354.1	457.6	353.4	459.6	352.9
<u>PNEUMATIC POWER CONTROL SYSTEM</u>									
Power Control Module Press Switch	7851830-521	600 ±21	490 ±31	593.3	486.3	599.7	496.0	598.1	488.7
LOX Chill Pump Motor Container	7851847-535	54.5 max	48.5 min	52.7	49.8	52.6	49.7	53.2	49.7
Engine Pump Purge Press Switch	1A67002-509 -005	136 max	99 min	122.6	110.6	124.7	112.7	121.0	110.0
<u>J-2 ENGINE</u>									
Mainstage OK No. 1	NAS-27453-1	515 ±25	P/U Minus 75 ±25	515.01	462.95	519.66	466.38	519.44	467.19
Mainstage OK No. 2	NAS-27453-1	515 ±25	P/U Minus 75 ±25	508.06	457.18	509.57	456.12	510.67	457.57

NOTE: All pressures listed are the average of 3 actuations.

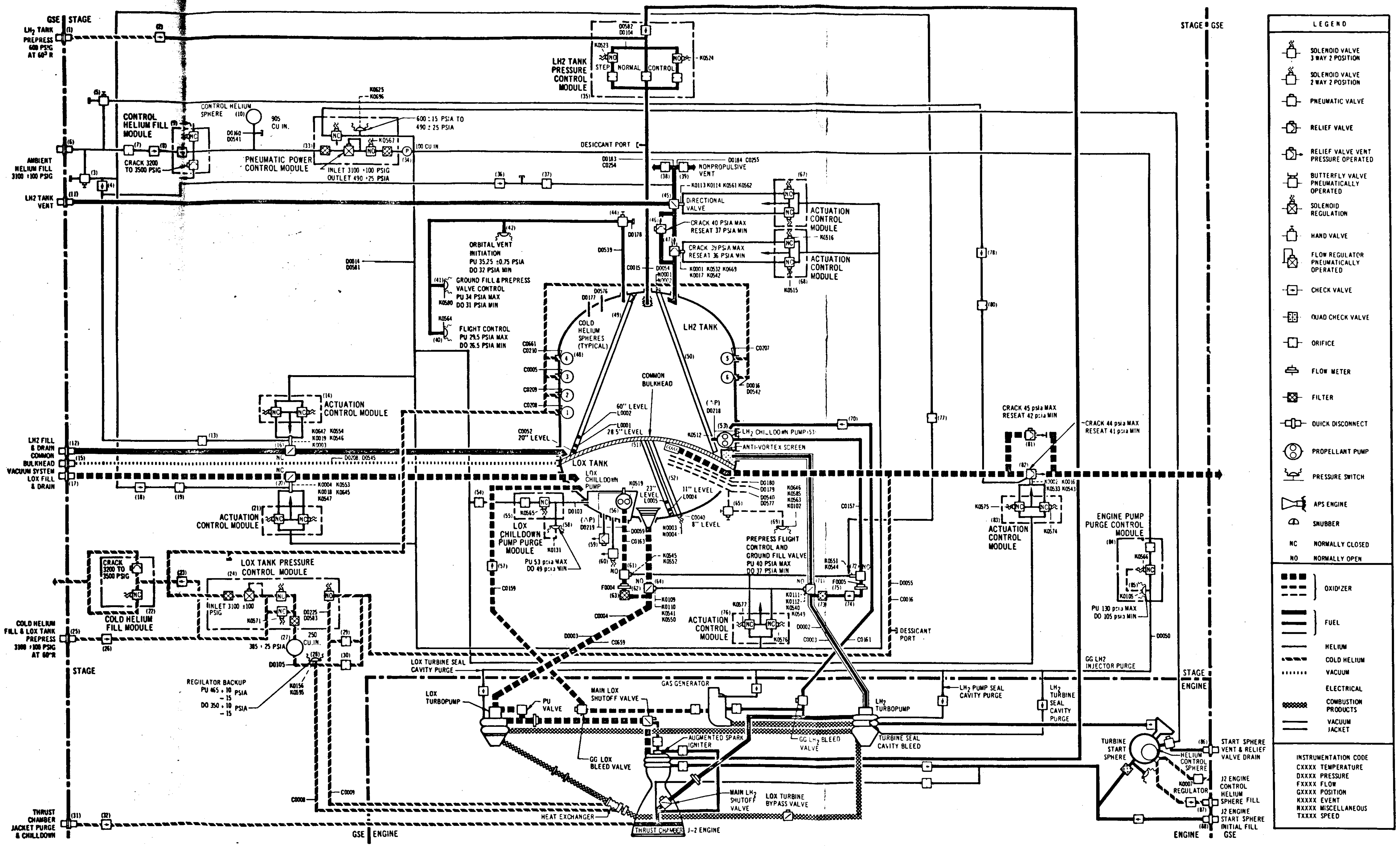


Figure 3-1. Propulsion System Configuration and Instrumentation

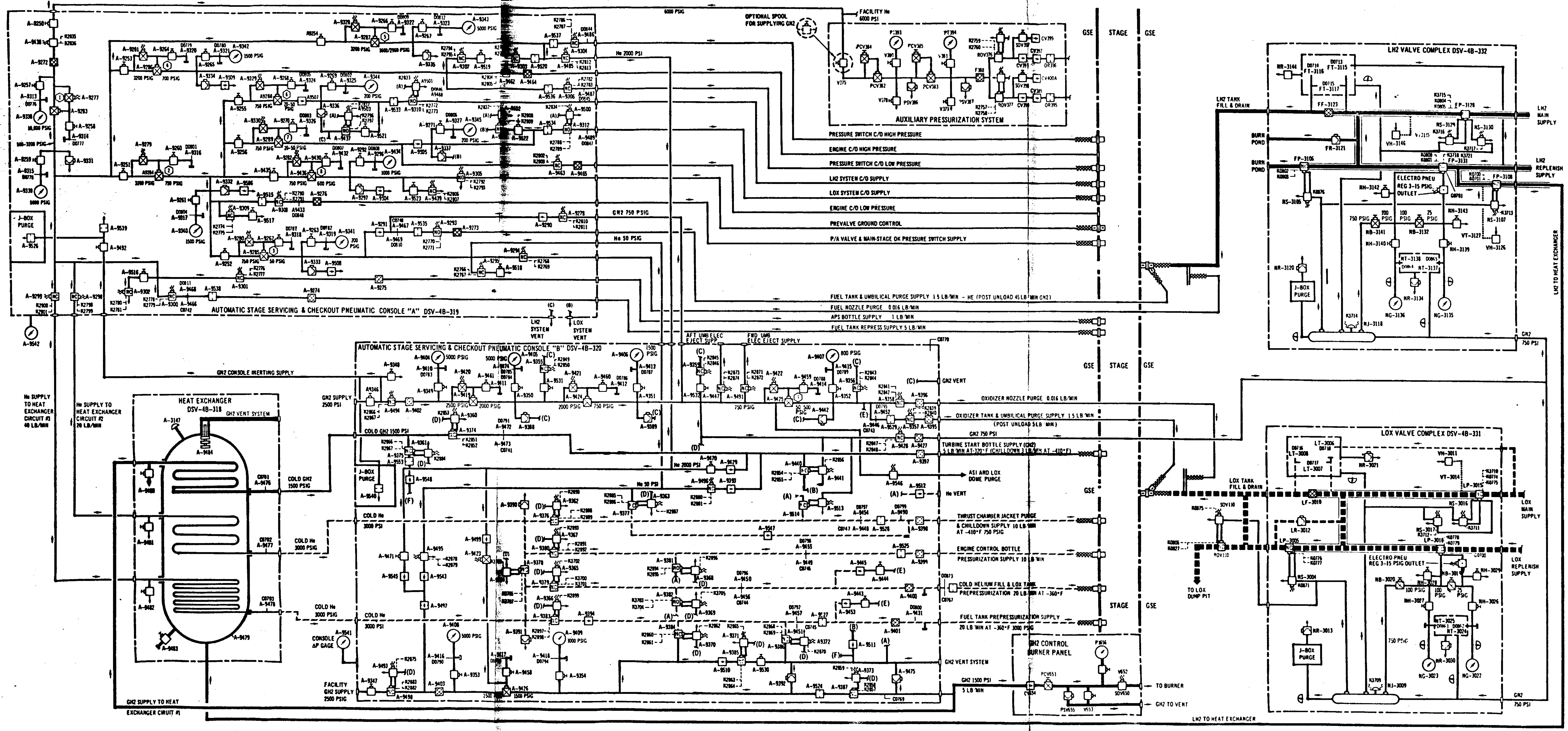


Figure 3-2. Facility Propellant and Pneumatic Loading Systems

4. COUNTDOWN OPERATIONS

The S-IVB-206 stage acceptance firing was successfully accomplished during CD 614070 on 19 August 1966. A postfiring inspection of the J-2 engine revealed discrepancies which necessitated replacement of the engine LOX turbopump; consequently, a short duration engine verification firing was performed during CD 614072 on 14 September 1966. All phases of the acceptance firing countdown are reviewed and evaluated in the following paragraphs, which include discussions of the prefiring checkout, propellant loading, and ground support and facility operation. The engine performance verification firing is not discussed unless it is pertinent to the analysis of the engine performance.

4.1 Countdowns

Three countdowns, CD 614069, CD 614070, and CD 614072, were necessary to satisfy all requirements of the S-IVB-206 stage acceptance firing program.

4.1.1 Countdown 614069

Countdown 614069 was initiated on 17 August and progressed without problem to T -8 hr when it was terminated upon request of A3 Development Engineering. It was requested that seven accelerometers be added to the LOX low pressure duct, because of a bellows failure during the formal qualification test.

4.1.2 Countdown 614070

Countdown 614070 was initiated on 18 August 1966 and was considered the official acceptance firing countdown. No significant stage problems were encountered, although an erratic indication from the vibration safety cutoff No. 1 was traced to a loose electrical connector. The following facility and GSE difficulties were encountered and corrected: (1) a faulty downrange igniter talkback (poor connector solder joint), (2) malfunctioning first stage manual helium regulator (moisture in regulator inlet), and (3) severe leakage of the LH2 replenish valve (corrected by retorquing the valve). LOX loading was nominal, but LH2 loading was interrupted three times and had to be completed using only the main fill valve due to the aforementioned leak. The propellant tank relief valve checks were performed satisfactorily, the stage pneumatic systems were pressurized, and the automatic terminal count was initiated. The automatic sequence was satisfactory and resulted in a successful firing. Significant countdown times are presented in the following table:

Event	Time
Simulated Liftoff (SLO)	1552:07.0 PDT
Engine Start Command (ESC)	SLO +150.77 sec
Engine Cutoff Command (ECC)	SLO +586.92 sec

4.1.3 Countdown 614072

During the acceptance postfiring checks of the turbines, damage was found in the LOX first-stage turbine blades and stator. The tOX turbopump was replaced, necessitating a short duration refiring to verify the calibration of the engine. This second firing was designated as an engine performance verification firing, run 3, revision II of TR 1309 and was conducted on 14 September 1966. The countdown proceeded smoothly with only a slight delay to investigate a backup power problem. Propellants were loaded in the normal manner, with the exception of a planned delay at 15 percent LOX to investigate previous depletion sensor problems. The automatic terminal count was nominal and was concluded with a 66.6 sec mainstage duration firing which satisfied the engine performance verification objective.

4.2 Checkout

The modifications, procedures, and checkouts performed for the acceptance firing were initiated on 30 June, upon receipt of the stage at Sacramento Test Center, and were continued through 16 August, when the stage was ready for the acceptance firing. The handling and checkout procedures that were used for the prefiring and postfiring checkouts are described in Douglas Report No. SM-56452, Narrative End Item Report on Saturn S-IVB-206, dated November 1966.

The integrated systems test which was completed on 10 August, checked out the automatically controlled equipment of the stage, pneumatic consoles, and propellant sleds. The simulated static firing was performed on 11 and 12 August to verify the countdown procedure. The test was completed satisfactorily, although some GSE pneumatic valves failed and had to be replaced.

4.3 Cryogenic Loading

The S-IVB-206 stage was successfully loaded with LOX, LH2, and cold helium. Satisfactory temperature and pressure levels were attained in all systems, although the LH2 loading operations were interrupted three times and completed under manual control.

4.3.1 LOX Loading

The LOX loading preparations were conducted as specified in Task 41 of the Countdown Manual, and computer controlled loading operations were initiated. The loading was satisfactorily completed without incident, although erratic indications were received from depletion sensor No. 3. The loading data are presented in table 4-1 and figure 4-1.

4.3.2 LH2 Loading

The LH2 loading preparations were completed and the operation initiated as specified in Task 42 of the Countdown Manual. One hour and forty one minutes were required to complete LH2 loading due to three interruptions in the operation caused by leakage at the facility valve sled. At approximately 16 percent LH2, loading was stopped when the leakage was first noted. After the valves were torqued, loading was reinitiated and leakage was again noted at 25 percent LH2. After some troubleshooting, it was possible to determine that the leakage was in the replenish valve; consequently, loading was resumed at the 30 percent level and completed using only the main fill valve. During the stand inspection, the leak was eliminated by tightening the packing glands and bonnet seal. Loading data are presented in figure 4-2 and table 4-2.

4.3.3 Cold Helium Loading

Cold helium was loaded after the completion of LH2 loading. Satisfactory temperatures and pressures were obtained. Data are presented in table 4-3 and figure 4-3.

4.4 GSE Performance

4.4.1 GH2 Supply System

The GH2 supply system performed adequately. The engine start sphere conditions were within the engine start requirements.

Ambient GH2 from the facility was supplied at 2,500 psia to console B where it was regulated to approximately 1,270 psia (figure 4-4). The GH2 was cooled by routing it through the No. 1 (GH2) circuit in the heat exchanger and returning it to pneumatic console B for control and distribution to the engine start sphere. Start sphere chilldown was accomplished by flowing the cold GH2 into the engine GH2 start sphere and out the sphere vent valve.

4.4.2 Helium Supply System

The helium supply system functioned adequately. Propellant tank prepressurization, thrust chamber chilldown, loading of the cold helium spheres, as well as the engine control sphere, were all satisfactorily accomplished.

The pneumatic control console A, stage 1 regulator helium supply pressure (D0778) profile was normal. The pressure was 3,025 psia from initiation of the thrust chamber chilldown until the start of prepressurization (figure 4-5). The regulated pressure then increased to 3,170 psia by the end of prepressurization.

The cold helium supply for pressurizing the engine control sphere and thrust chamber chilldown was satisfactory. The engine control sphere was pressurized to 3,008 psia. The temperature decreased to 257 deg R at the end of start sphere chilldown. By engine start the pressure had been increased to 3,150 psia, and the temperature had increased to 261 deg R as a result of start sphere loading (figure 4-5). Both gas heat exchanger outlet temperatures (figures 4-6 and 4-7) reacted as expected. The four-coil outlet was stable at 50 deg R and the eight-coil outlet was 44 deg R throughout chilldown until LOX tank prepressurization was initiated. The steady state temperature at the thrust chamber jacket chilldown control orifice approached 90 deg R. The cold helium flowrate during thrust chamber chilldown was a normal 9 to 11.5 lbm/min (figure 4-7).

4.5 Terminal Count

The major events of the terminal count were engine conditioning and final replenishing and prepressurization of the propellant tanks. They included final addition of helium to the cold helium spheres and the stage pneumatic control sphere, chilldown of the thrust chamber, engine start sphere, engine pumps, and pressurization of the start sphere.

The terminal count started with the automatic sequence at SLO -25 min and proceeded through the scheduled events without incident. The final portion of the terminal count commenced with the initiation of propellant tank prepressurization at SLO -161 sec; final propellant replenishing was completed by SLO -44 sec. Cold helium sphere fill was terminated at SLO -4.2 sec and engine pump purges terminated at SLO +89.4 sec, approximately as planned.

4.6 Holds

The apparent hold time during CD 614070 was 14 hr 14 min. The countdown clock appears to have been advanced from T -12 hr to T -8 hr at the beginning of the planned hold (1955 PDT, 18 August); however, inconsistencies in the available data leave 1 hr, 40 min of time unaccounted for. The individual hold periods are defined as follows:

Time from T (hr, min)	Real Time (PDT)	Duration (hr, min)	Reason
-16:37	1121 (18 Aug)	3:56	Troubleshooting and repairing engine safety cutoff system problem
-8:00	1955	6:35	Planned hold
-3:30	0718 (19 Aug)	2:23	Repair GSE regulator Repair talkback amplifier
-2:15	1141	1:20	Troubleshoot and repair LH2 leak on valve sled

TABLE 4-1
LOX LOADING DATA

S-IVB STAGE	CD	INITIAL SLOW FILL			RAPID FILL			FINAL SLOW FILL			TOTAL LOAD TIME (sec)	TOTAL MASS LOADED (lbm)
		TIME (sec)	FLOW-RATE (gpm)	MASS+ (%)	TIME (sec)	FLOW-RATE (gpm)	MASS+ (%)	TIME (sec)	FLOW-RATE (gpm)	MASS+ (%)		
201	614040	970	332	2.5	830	1,075	94	215	323	100	2,015	192,551
202	614047	345	141	4	1,140	1,030	100	NA	NA	NA	1,485	--
	614048	348	157	4.5	1,135	1,007	98.5	65	280	100	1,548	--
	614050	345	144	5.5	1,131	1,002	98.75	64	235	100	1,540	190,626
203*	614054	DNA	DNA	DNA	DNA	DNA	DNA	DNA	DNA	DNA	DNA	--
	614055	620	126	10.4	665	1,005	99.5	22	165	100	1,307	--
	614056	583	136	12.5	650	1,025	99.5	30	120	100	1,263	114,319
204	614059	373	255	7.8	1,085	1,012	98	94	195	100	1,552	187,633
501	614061	DNA	DNA	DNA	DNA	DNA	DNA	DNA	DNA	DNA	DNA	--
	614063	531	165	7	1,119	1,007	97	147	119	98.4	1,797	187,248
205	614064	399	157	5.15	1,130	1,021	100	NOT PERFORMED			1,529	189,957
502	614067	524	168	7.2	1,193	944	99.1	138	80	100	1,895	193,325
206	614070	417	219	7.4	1,105	1,014	97.9	142	182	100	1,664	194,094

DNA - Data not available
+ 100% mass is defined as mass at simulated liftoff
* 100% mass was considerably less than nominal (62%) for the S-IVB configuration in conjunction with the stage primary mission - the LH2 experiment.

TABLE 4-2
LH2 LOADING DATA

S-IVB STAGE	CD	INITIAL SLOW FILL			RAPID FILL			FINAL SLOW FILL			TOTAL LOAD TIME (sec)	TOTAL MASS LOADED (lbm)
		TIME (sec)	FLOW-RATE (gpm)	MASS+ (%)	TIME (sec)	FLOW-RATE (gpm)	MASS+ (%)	TIME (sec)	FLOW-RATE (gpm)	MASS+ (%)		
201	614040	1,000	815	20	930	3,040	94	420	863	100	2,350	37,079
202	614047	260	589	4	1,240	2,935	99	Not performed because of GSE loading problems			1,500	--
	614048	292	524	4	1,207	3,015	99				1,499	--
	614050	300	511	4	1,211	3,000	99				1,511	37,587
203*	614054	DNA	DNA	DNA	DNA	DNA	DNA	DNA	DNA	DNA	DNA	--
	614055	509	465	5	1,445	2,910	98.3	225	396	100.2	2,180	--
	614056	498	495	5	1,430	2,930	98	200	434	100	2,128	44,167
204	614059	433	690	8	1,229	2,706	97	133	880	100	1,795	36,785
205	614064	330	672	5.9	1,215	2,891	100	NOT PERFORMED			1,544	36,344
501	614061	DNA	DNA	DNA	DNA	DNA	DNA	DNA	DNA	DNA	DNA	--
	614063	486	601	7	1,387	2,887	103	174	335	104.4	2,047	38,792
502	614067	533	509	6.5	1,409	2,730	98.6	143	409	100	2,085	40,452
206	614070++	260	977	6.8	++	++	97.1	117	639	99.1	++	36,730

DNA - Data not available
+ 100% mass is defined as mass at simulated liftoff.
* 100% mass was considerably more than nominal (118%) for the S-IVB/IB configuration (and thus took more time than usual) in conjunction with the stage primary mission, the LH2 experiment.
++ Three delays and abnormal loading procedure were necessitated by leakage on the LOX valve skid; duration and flowrates are not comparable.

TABLE 4-3
COLD HELIUM LOADING DATA

S-IVB STAGE	CD	INITIAL PRESSURE (psia)	TIME TO ACHIEVE 3000 psia* (sec)	TIME TO ACHIEVE 50°R (sec)	PRESSURE AT SLO (psia)	TEMPERATURE AT SLO (°R)	LOADED MASS (lbm)
201	614040	1,500	200	900	3,200	40	342
202	614047	750	400	860	3,240	40.4	370
	614048	760	500	920	3,190	39.5	371
	614050	785	670	1,030	3,100	38.5 (H/W) 41.5 (T/M)	346
203	614054	DNA	DNA	DNA	DNA	DNA	DNA
	614055+	734/1,415	N/A/1,153	716/664	N/A/2,990	N/A/41	334
	614056	750	756	940	3,000	42	330
204	614059	730	300	1,000	3,165	41.2	337
501	614061	645	550	1,080	3,185	40.0	346
	614063	750	350	1,020	3,155	40.0	340
205	614064	830	354	914	3,050	39.5	338
502	614067	900	340	1,007	3,150	40.2	336
206++	614070	960	4,040	1,265	3,020	40.0	251

N/A - Not applicable
DNA - Data not available
\+ The cold helium spheres were vented to 1,500 psia after attaining 2,920 psia, to permit repairs to the gas heat exchanger relief valves. The spheres were then repressurized.
* Elapsed time after start of cold helium loading.
++ S-IVB-206 was the first stage to utilize only 6 cold helium spheres.

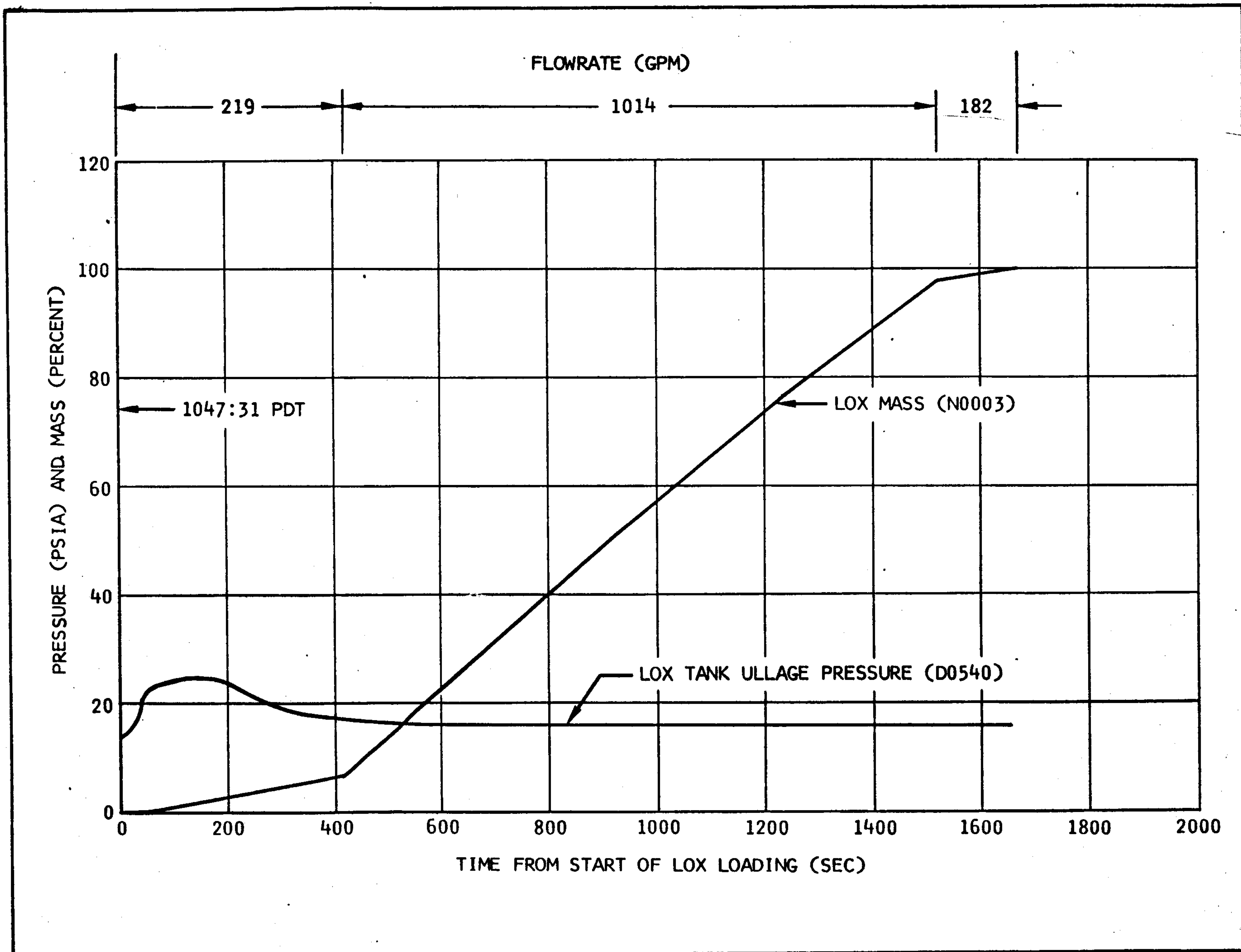


Figure 4-1. LOX Tank Loading

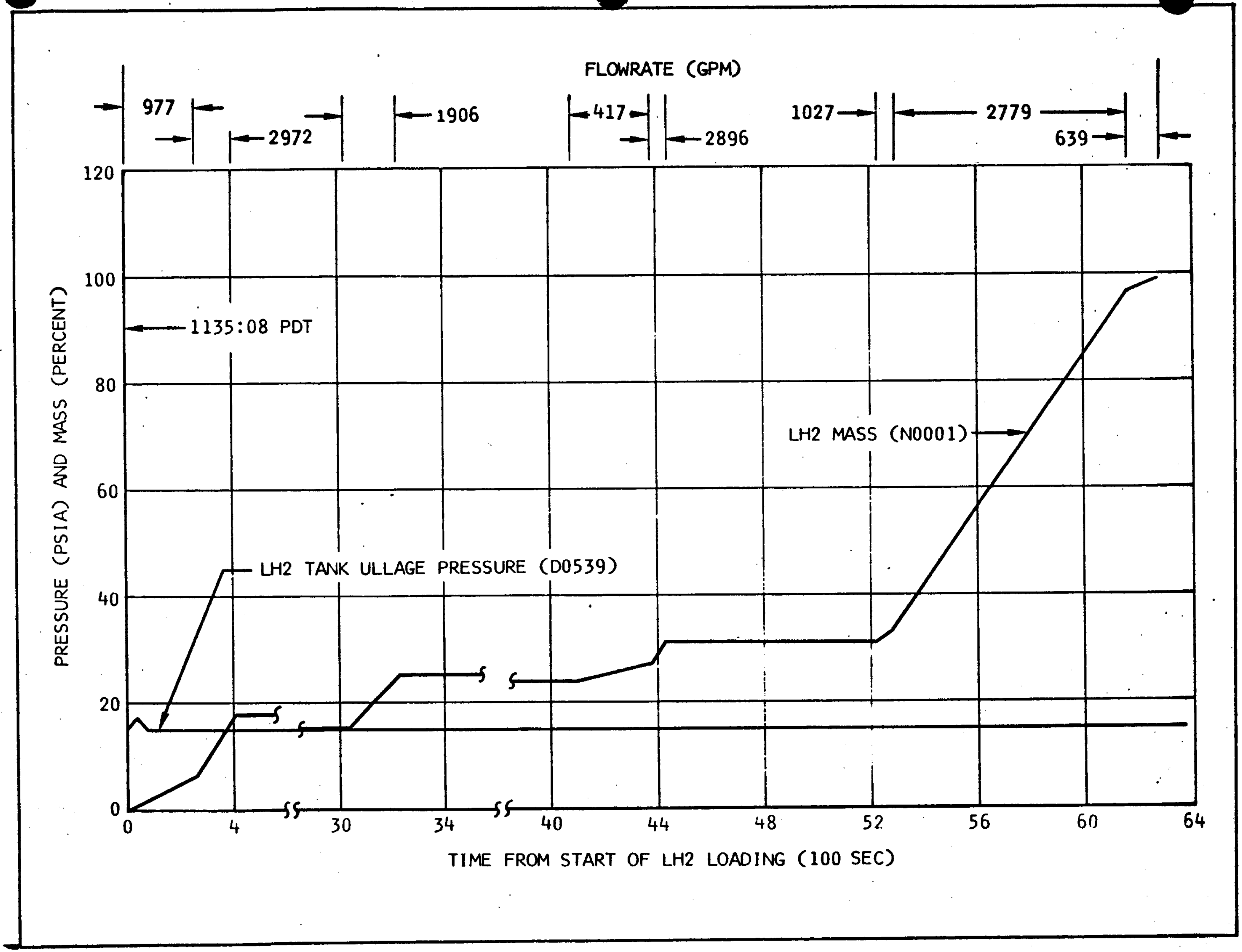


Figure 4-2. LH2 Tank Loading

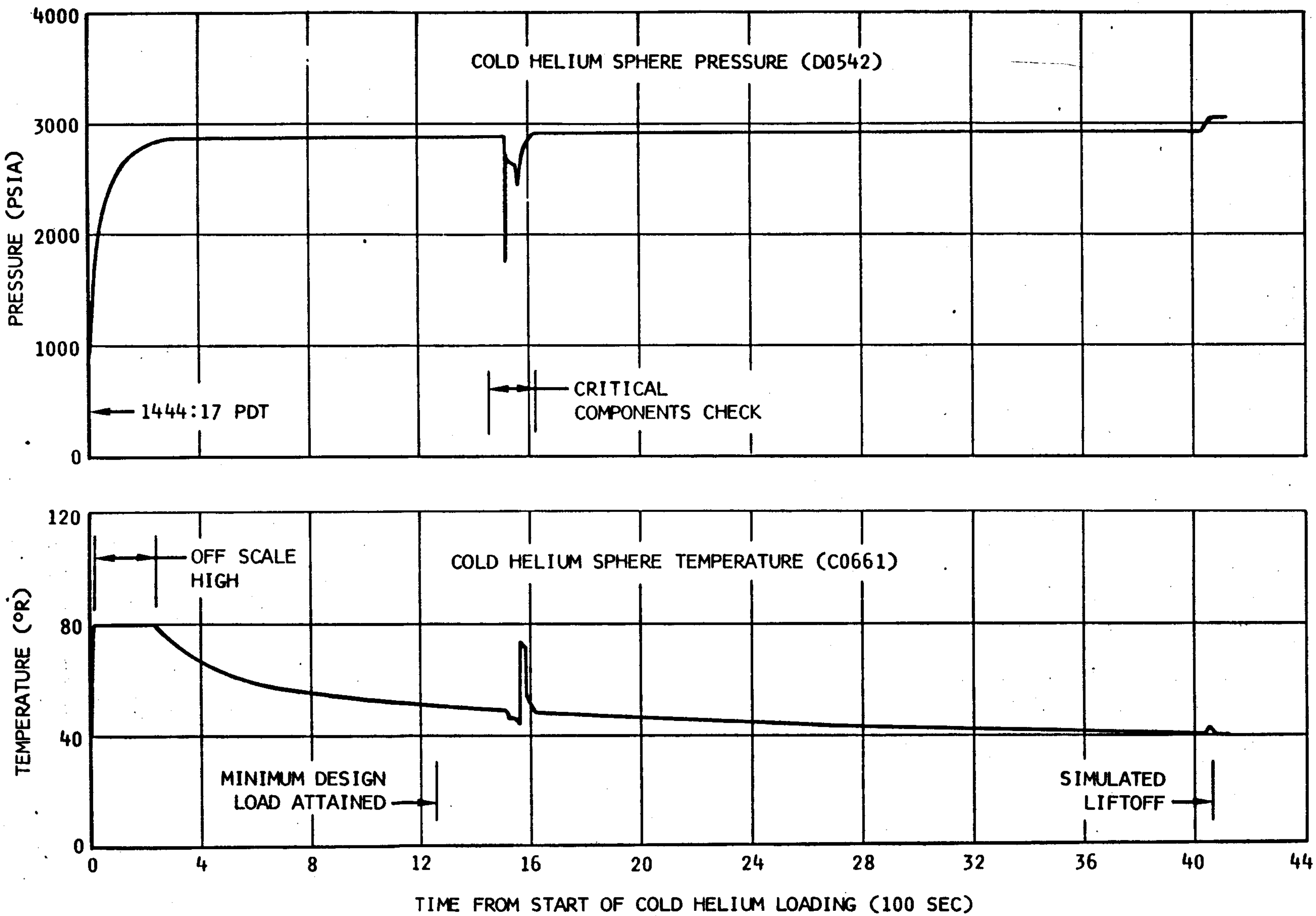


Figure 4-3. Cold Helium System Loading

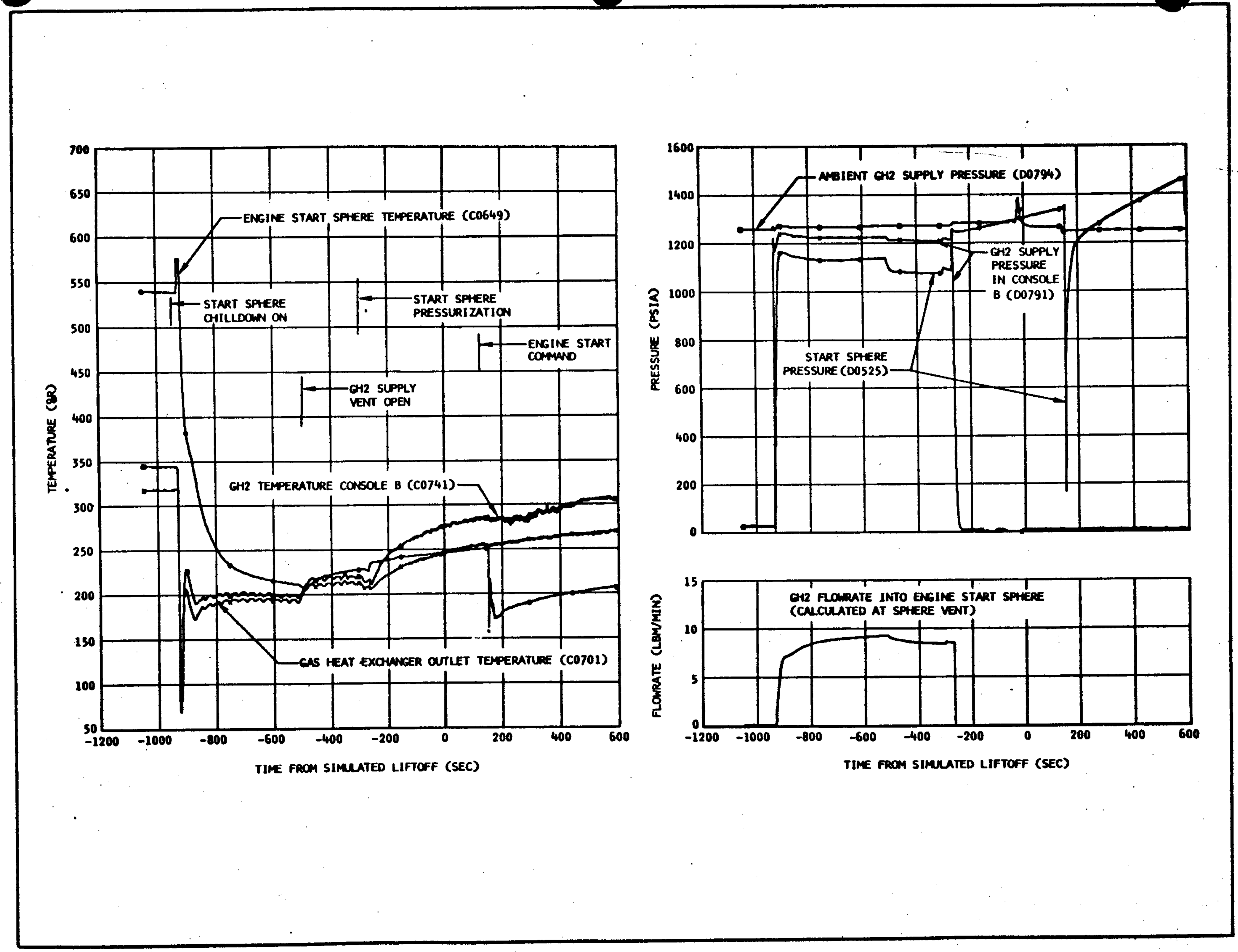


Figure 4-4. GSE Performance During Engine Start Sphere Childown and Loading

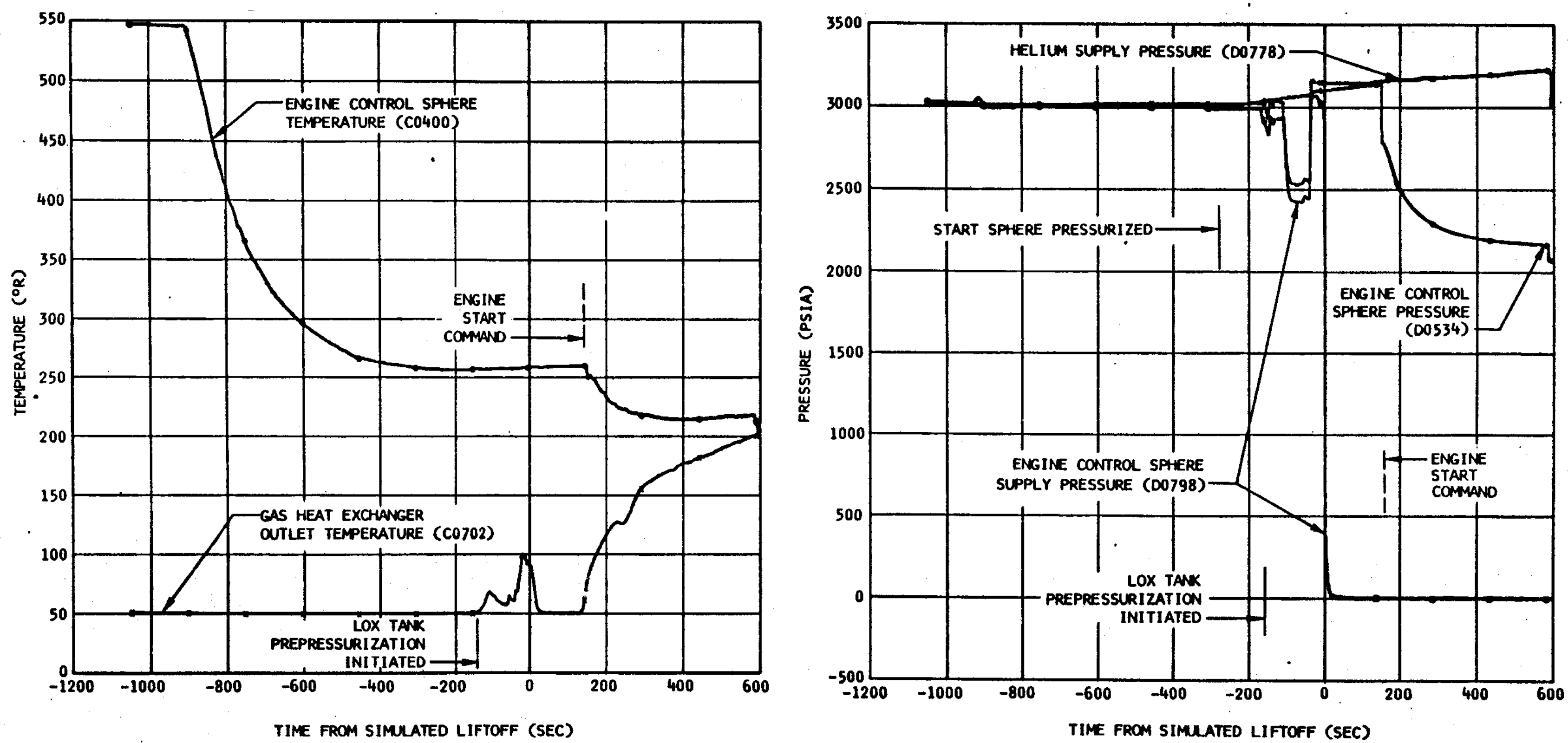


Figure 4-5. GSE Performance During Engine Control Sphere Loading

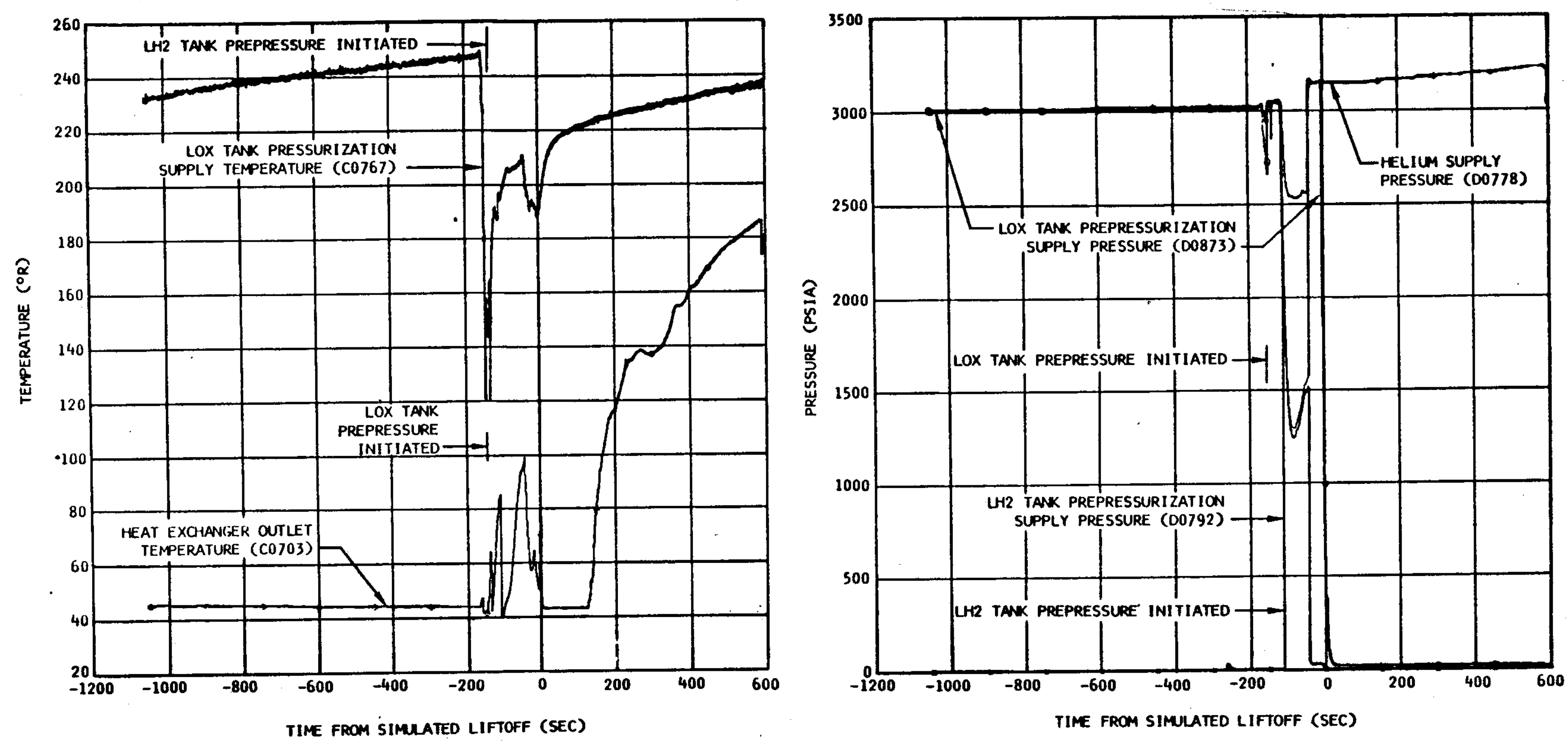


Figure 4-6. GSE Performance During LOX and LH2 Tank Prepressurization

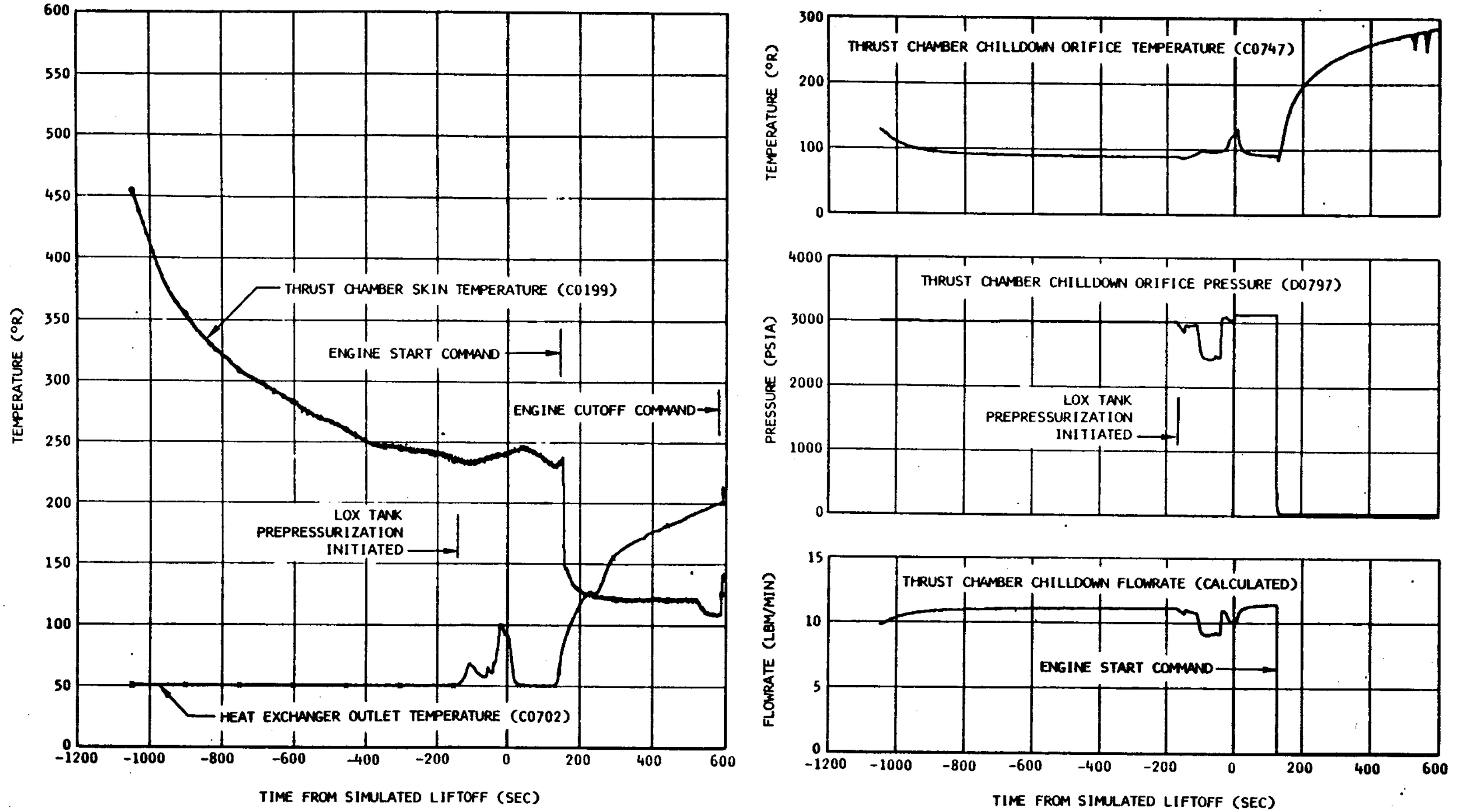


Figure 4-7. GSE Performance During Thrust Chamber Chilldown

5. SEQUENCE OF EVENTS

The S-IVB-206 stage acceptance firing sequence of events is presented in table 5-1. Event times from two data sources are included in the table. These sources were the Digital Events Recorder (DER/CAT 57), and PCM/FM Sequence (CAT 42). Accuracies of the listed events are as follows:

DATA SOURCE	ACCURACIES
Digital Events Recorder (DER/CAT 57)	+0, -1 ms
PCM/FM	
Discrete Bi-Level (CAT 42)	+0, -9 ms

TABLE 5-1 (Sheet 1 of 4)
SEQUENCE OF EVENTS

EVENT/RESULT OF COMMAND	SWITCH SELECTOR CHANNEL	CAT 57 DIGITAL EVENT RECORDER	PCM SEQUENCE CAT 42
Launch Automatic Sequence Start			
Auxiliary Hydraulic Pump On	28	-608.392	
Auxiliary Hydraulic Pump Coast Mode Off	31	-608.360	
LOX Childown Pump On	22	-308.300	
LH2 Childown Pump On	58	-305.121	
Engine Pump Purge Control Valve Open	24	-90.4	
Engine Pump Purge Control Valve Closed	25	+89.426	
Internal Power Transfer			
Simulated Liftoff (T_o*)		*0.00	
Inflight Cal On		90.871	
Inflight Cal Off		91.980	
Ullage Rocket Chg On Cmd	54	141.186	
EBW Charge 1-1		141.192	
EBW Charge 1-2		141.192	
EBW Charge 2-1		141.192	
EBW Charge 2-2		141.192	
EBW Charge 3-1		141.192	
EBW Charge 3-2		141.192	
Ullage Rocket Fire Cmd	56	145.708	
EBW Fire 1-1			145.746
EBW Fire 1-2			145.746
EBW Fire 2-1			145.754
EBW Fire 2-2			145.754
EBW Fire 3-1			145.754
EBW Fire 3-2			145.754
Prevalve Open Cmd		146.353	
LH2 Prevalve Open		149.109	149.146
LOX Prevalve Open		149.046	149.146
LH2 Childown Pump Off Cmd	59	150.166	
Engine Cutoff Off Cmd	13	149.850	
Engine Cutoff Command On (Dropout)		149.859	

*T_o = 15:27:07.000 Range Time

TABLE 5-1 (Sheet 2 of 4)
SEQUENCE OF EVENTS

EVENT/RESULT OF COMMAND	SWITCH SELECTOR CHANNEL	CAT 57 DIGITAL EVENT RECORDER	PCM SEQUENCE CAT 42
LH2 Chilldown Pump Off		150.172	
LOX Chilldown Pump Off Cmd	23	150.254	
LOX Chilldown Pump Off		150.260	
LOX Chilldown Valve Closed		150.306	
LH2 Chilldown Valve Closed		150.344	
Engine Start Command (ESC)	9	150.761	*150.769
Thrust Chamber Spark Sys On		150.767	150.769
Gas Generator Spark On		150.767	150.769
Helium Control Solenoid Energized		150.767	150.769
Engine Ready Signal Off		150.770	150.821
Engine Start On		150.789	150.802
Ignition Phase Control Solenoid Energ		150.795	150.769
Main Fuel Valve Closed (Dropout)		150.819	
Main Fuel Valve Open			150.904
Ignition Detected			150.986
Engine Start Off Cmd	27	151.367	
Engine Start Off		151.391	
Start Tank Discharge Valve Close (Dropout)		151.557	
Start Tank Discharge Valve Open		151.645	151.654
LOX Tank Flight Pressure System On Cmd	103	151.656	
Mainstage Control Solenoid Energized			151.852
Main Oxidizer Valve Closed (Dropout)		151.953	
Gas Generator Valve Closed (Dropout)		151.947	
Start Tank Discharge Valve Open (Dropout)		151.958	151.987
Gas Generator Valve Open		152.064	152.071
Oxidizer Turbine Bypass Open (Dropout)		152.107	152.162
Oxidizer Turbine Bypass Valve Closed		152.292	152.329
Mainstage Pressure Switch Depress B Dropout			153.429
Mainstage Pressure Switch Depress A (Dropout)			153.429
Mainstage OK		153.415	153.487

*ESC = T_o +150.769

TABLE 5-1 (Sheet 3 of 4)
SEQUENCE OF EVENTS

EVENT/RESULT OF COMMAND	SWITCH SELECTOR CHANNEL	CAT 57 DIGITAL EVENT RECORDER	PCM SEQUENCE CAT 42
Engine Burn No. 1 On Cmd	68	153.770	
Engine Burn No. 1 On (LH2 Tnk Step Press Cont/Sol)		153.778	
Main Oxidizer Valve Open		154.333	154.404
Gas Generator Spark System Off		155.154	155.160
Thrust Chamber Spark System Off		155.156	155.160
PU Activate Cmd	5	157.060	
PU Activate		157.065	
Ullage Rocket Jettison Charge On Cmd	55	174.914	
Ullage Rocket Jettison Fire On Cmd	57	178.031	
Ullage Jettison Charge Cmd Reset	88	178.152	
EBW Fire 1			178.087
EBW Fire 2			178.087
Ullage Jettison Fire Cmd Reset	73	178.239	
Auxiliary Hydraulic Pump Off Cmd	29	335.635	
Auxiliary Hydraulic Pump Off		335.639	
Auxiliary Hydraulic Pump On Cmd	28	451.809	
Auxiliary Hydraulic Pump On		451.812	
First Burn Relay Off Cmd	69	451.900	
First Burn Relay Off		451.907	
Point Level Sensor On Cmd	97	580.246	
Non-Programmed Engine Cutoff		*586.913	
Cutoff Lock-In Indicated		586.915	586.987
Ignition Phase Control Solenoid De-energized			586.919
Mainstage Control Solenoid De-energized			586.919
Engine Cutoff Cmd On	12	587.153	
Main Oxidizer Valve Open (Dropout)		587.007	
Gas Generator Valve Open (Dropout)		587.017	
Main Fuel Valve Open (Dropout)		587.043	
Engine Pump Purge Control Valve Open Cmd	24	587.240	
Gas Generator Valve Closed		587.135	

* Engine cutoff occurred at T_o +586.913

TABLE 5-1 (Sheet 4 of 4)
SEQUENCE OF EVENTS

EVENT/RESULT OF COMMAND	SWITCH SELECTOR CHANNEL	CAT 57 DIGITAL EVENT RECORDER	PCM SEQUENCE CAT 42
Mainstage Pressure Switch B Depress		587.113	587.179
Mainstage Pressure Switch A Depress		587.115	587.179
Main Oxidizer Valve Closed		587.124	
Main Fuel Valve Closed		587.226	
Fuel Prevalve Open (Dropout)		587.481	587.562
Oxidizer Prevalve Open (Dropout)		587.480	587.562
Fuel Prevalve Closed		587.731	587.812
Oxidizer Prevalve Closed		587.873	587.896
Helium Control Solenoid De-energized			587.894
Coast Period On Cmd	79	588.270	
Engine Start Off Command	27	588.589	
LH2 Chilldown Pump Off Command	59	588.798	
LOX Chilldown Pump Off Command	23	588.894	
PU Activate Off Cmd	6	590.172	
PU Activate Off		590.175	
Point Level Sensors Disarm Cmd	98	590.302	
Ullage Jettison Charge Command Reset	88	591.774	
First Burn Relay Off Command	69	591.888	
Ullage Jettison Fire Command Reset	73	591.976	

6. ENGINE SYSTEM

The S-IVB-206 acceptance firing was performed with Rocketdyne engine S/N J-2046 (figure 6-1) mounted on the stage. The firing time of this engine was accumulated as follows:

Test	Time (sec)
Rocketdyne	439.7
Sacramento Test Center	
CD 614070	436.15
CD 614072	68.98
Total	944.83

Countdown 614070 was a full-duration acceptance firing; CD 614072 was an engine performance verification firing that was required when the complete LOX turbopump assembly (paragraph 6.5) was replaced because of a damaged LOX turbine seal that was discovered after the acceptance firing.

After the engine was delivered to Douglas but before the acceptance firing, an orifice was installed in the gas generator (GG) valve control line (ECP 455-R3) in order to improve the start transient characteristics of the engine (paragraph 6.4.1). This was the only change that affected engine performance.

6.1 Engine Chilldown and Conditioning

6.1.1 Engine Turbopump Chilldown

Chilldown of the engine LOX and LH2 turbopumps was adequate to provide the conditions required for proper engine start. An analysis of the chilldown operations is presented in paragraphs 7.3 and 8.2.

6.1.2 Thrust Chamber Chilldown

6.1.2.1 Acceptance Firing - CD 614070

The thrust chamber skin temperature was 235 deg R at Engine Start Command (figure 6-2), well within the engine start requirement of 260 ±50 deg R. The LH2 pump demonstrated satisfactory start transient buildup characteristics (figure 6-3).

Childown was initiated at SLO -1,201 sec and terminated at SLO +126 sec. The temperature decreased steadily until SLO -105 sec when it reached its lowest value; subsequently, the temperature went through a fluctuation due to a demand on the helium supply by the LOX and LH2 prepressurization. The flow of cold helium was interrupted sufficiently to cause the thrust chamber to warmup during prepressurization. At the end of chilldown, the temperature was 232 deg R. Further information on the chilldown operation and GSE supply system is presented in section 4.

6.1.2.2 Engine Verification Firing - CD 614072

The thrust chamber chilldown was more rapid than that of the acceptance firing; however, because of a leak in the GSE cold helium crossover valve, the chilldown was terminated at SLO -5 sec and the thrust chamber skin temperature increased to 264 deg R at Engine Start Command (figure 6-2). The effects of this higher temperature are apparent in the LH2 pump start transient performance (figure 6-4). Both thrust chamber temperature and pump start transient were, nevertheless, well within acceptable limits.

6.1.3 Engine Start Sphere Chilldown and Loading

Chilldown and loading of the engine GH2 start sphere met the required objectives. Start sphere performance is graphically presented in figure 6-5. The GH2 supply system performance during start sphere chilldown and loading is described in section 4. The start sphere warmup rate from pressurization to blowdown was 2.6 deg/min. Total GH2 usage during engine start was 3.12 lbm. The system demonstrated satisfactory repressurization during engine burn; however, the sphere relief valve failed to open and caused a pressure buildup to 1,463 psia. The valve was replaced after the firing. Significant start sphere performance values were as follows:

Event	Temperature (deg R)	Pressure (psia)	GH2 Mass (lbm)
Engine Start Command	252	1,346	3.95
After Sphere Blowdown	156	184	0.83
Engine Cutoff	207	1,463	5.24

6.1.4 Engine Control Sphere Childown and Loading

Engine control sphere conditioning was adequate and all objectives were satisfactorily accomplished (figure 6-5). Total helium usage during the engine firing was 0.34 lbm. Significant control sphere performance values were as follows:

Event	Temperature (deg R)	Pressure (psia)	Helium Mass (lbm)
Engine Start Requirement	290 $\pm$30	3,000 $\pm$200	
Engine Start Command	261	3,150	2.15
Engine Cutoff	217	2,157	1.81
Total Helium Usage			0.34

6.2 J-2 Engine Performance Analysis Methods and Instrumentation

Engine performance for both the acceptance and verification firings was calculated by use of computer programs G105-3 and F823-1. A description of the operation and comparison of the results of each program is presented in table 6-1. Computer program AA89 was not used to calculate the performance of either firing for the following reasons:

a. Program AA89 results would not reflect the effect of the LOX turbopump performance degradation during the acceptance firing

b. After the acceptance firing because the LOX turbopump was changed, no new valid engine tag values were available for use in program AA89 to evaluate the verification firing.

Several biases were necessary to correct for known data discrepancies. The main chamber pressure (Pc) was biased -15 psi for both firings. From an analysis of the raw test pip count data for both firings, engine flow-rates were biased as follows:

Firing	LOX (gpm)	LH2 (gpm)
Acceptance	+22.49	-386.79
Engine Verification	+25.02	-385.84

During the engine verification firing, the time sequence of events was lost and the LOX turbine inlet pressure became pegged off the high scale. Indications of this measurement being invalid appeared during the acceptance firing. The Douglas engine performance evaluation computer programs do not use this measurement; however, it is a significant parameter used to monitor performance of the turbine drive system.

6.3 J-2 Engine Performance

The engine performance was satisfactory through the mainstage operation except for the LOX turbopump malfunction during the acceptance firing. During the engine verification firing, engine operation with the new LOX turbopump assembly was satisfactory. Plots of selected data used as inputs to the computer programs listed in table 6-1 are presented in figures 6-6 through 6-17. The engine propellant inlet conditions are presented in sections 7 and 8. Steady-state computer performance parameters are presented in figures 6-18 through 6-21.

The J-2 engine performance was reconstructed from engine start to cutoff for both the acceptance firing and the engine performance verification firing. The results of two computer program reconstructions were combined to obtain the final values for engine performance as presented in table 6-1.

The average results of these programs agreed within the following accuracies for both firings:

Parameter	Acceptance Firing	Engine Performance Verification Test
Thrust (%)	0.025	0.005
Total Propellant Flowrate (%)	0.028	0.075
Specific Impulse (%)	0.056	0.094
Engine Mixture Ratio (%)	0.112	0.132

6.3.1 Start Transient

The J-2 engine start transient was satisfactory for both the acceptance and verification firings. A summary of engine performance values is presented in the following table:

	Acceptance Firing	Verification Firing	Log Book
Time to 90 percent performance level (sec)	3.318	3.171	2.3*
Thrust Rise Time (sec)	2.174	2.031	1.89
Total Impulse (lbf-sec)	193,052	173,860	160,972**
Maximum rate of Thrust Increase (lbf/ioms)	8,533	9,669	40,000***

* = Referenced to start tank discharge valve. Acceptance and verification: start tank discharge control solenoid energized at 643 ms and 640 ms, respectively.

** = Based on stabilized thrust at null PU and standard altitude conditions.

*** = Maximum allowable.

Thrust buildup to the 90 percent performance level (thrust chamber pressure = 618 psia) was very close for the acceptance and verification firings as shown in figure 6-22. The deviation in total impulse from the acceptance to the verification firing is due to the slightly faster transient on the verification firing, as is shown by the thrust rise time (time from first indication of thrust to the 90 percent performance level) shown in the previous table. Figure 6-22 shows the thrust chamber pressure during start transient and the thrust buildup to the 90 percent performance level for the acceptance and verification firings as determimed by computer program F839. As expected, there was no thrust overshoot during the start transient.

6.3.2 Steady-State Performance

During the steady-state portion of the acceptance firing, a LOX turbopump malfunction caused a performance degradation. The engine started normally and the firing progressed satisfactorily until approximately ESC +60 sec when the effect of the malfunction became apparent in the data (figure 6-18). The performance then gradually decayed until ESC +366 sec (EMR cutback) when the values were 224,322 lbf thrust, 422.8 sec specific impulse, and 5.420 mixture ratio.

Table 6-2 compares the overall average performance values for steady-state operation with predicted. This table also compares the average performance during the closed PU valve portion of the test with predicted values and shows that the actual values prior to ESC +60 sec were in extremely close agreement with the prediction.

The actual average LOX flowrate prior to the malfunction was 457.656 lbm/sec which agrees closely with the prediction of 458.384 lbm/sec. At the time of the performance cutback, the LOX flowrate had decayed to 447.906 lbm/sec as shown in figure 6-18, lowering the average flowrate during closed PU valve operation. As compared to the predicted value, this LOX flowrate deviation caused the PU valve to remain closed 46 sec longer than predicted to reduce the equivalent LOX mass error to the cutback value (1,000 lbm). The remaining deviation between the predicted and actual PU valve cutback is explained in section 10.

The amount of propellants consumed (determined by the flow integral method) from Engine Start Command to Engine Cutoff Command (ESC +436.15 sec) was 36,134 lbm LH2 and 191,879 lbm LOX. The total impulse generated during this time was 96.95 10^6 lbm-sec. Extrapolating the usable propellants indicated that LOX depletion would have occurred 4.54 sec after Engine Cutoff Command, for a total burn to depletion of 440.69 sec as compared to the predicted value of 453.59 sec. The 12.90 sec deviation was due to the increase in overall average LOX flowrate (442.16 actual, 429.24 predicted) caused by the extended closed PU valve operation and the higher than predicted flowrates during operation at referenced mixture ratio (RMR).

There was sufficient information from this firing to calibrate the propellant utilization system so only a short refire was deemed necessary to verify engine performance. The engine verification firing demonstrated satisfactory engine performance. The test was terminated at ESC +68.982 sec while the PU valve was closed. The average performance while the valve was closed was 228,922 lbf thrust, 420.43 sec specific impulse, and 5.537 mixture ratio. The performance profiles of the verification firing are shown in figure 6-20.

The engine thrust variations during the acceptance firing are presented in table 6-3. Expanded thrust plots during the periods discussed are presented in figures 6-23, 6-24, and 6-25. Comparison is made to acceptance firing thrust history predictions and to Marshall Space Flight Center (MSFC) suggested allowable limits for flight. These limits do not apply to acceptance firing performance and are presented for reference purposes only. Thrust variations during flight will be modified by flight dynamics effects on stage operation such as propellant slosh. The thrust variations during the following four periods were reported:

a. PU valve hardover - (EMR = 5.5/1.0)

b. PU valve cutback +50 sec to ECC -70 sec

c. ECC -70 sec to ECC - (Includes transient PU valve operation)

d. ECC -40 sec to ECC (Includes stable PU valve response).

The thrust variations during hardover operation were within the suggested allowable flight limits and very close to predictions for the maximum rate and maximum amplitude of thrust variation. The thrust variations during this time period were caused by engine stabilization and stage perturbations including the main factors of variation in propellant supply conditions.

The time period from PU valve cutback +50 sec to ECC -70 sec was nonexistent during this firing because of the late PU valve cutback which was caused primarily by the variation in propellant consumption rates resulting mainly from the damaged LOX turbopump during the acceptance firing (paragraph 6.5).

The time period from ECC -70 sec to Engine Cutoff Command includes both transient performance results. The transient performance during this period was caused by the late PU valve cutback discussed above. Because of this phenomena the suggested allowable limits were exceeded in all categories. These results should not recur during the stage flight test as the LOX turbopump assembly was replaced and its performance verified during the short verification firing. Propellant utilization system calibration will also reduce cutback time deviations during the flight. It should be noted that the deviation in PU valve cutback time exceeded the maximum 3-sigma deviations predicted for a calibrated flight stage ($\pm$45 sec).

The time period from ECC -40 sec to Engine Cutoff Command is reported in addition to the normal periods discussed in an effort to show what the stable engine thrust deviations would produce excluding effects from the transient PU valve performance during mixture ratio cutback. The thrust variations during this period are influenced primarily by movements of the propellant utilization valve and, to a secondary degree, by variations in stage performance. The thrust variations during this period are within the suggested allowable flight limits.

6.3.3 Cutoff Transient

The time lapse between engine cutoff, as received at the J-2 engine, and thrust decay to 11,250 lbf was not within the maximum allowable time (800 ms) for the acceptance firing or for the engine verification firing as shown in the following table:

	Acceptance	Verification	Log Book
Thrust decay time to 11,250 lbf (ms)	823	812	365
Total impulse (lbf-sec)	51,311*	57,333**	40,750***

* = PU valve at -4.08 deg

** = PU valve at +33 deg

*** = PU valve at null position; standard altitude conditions; average of tests 313-093 and 313-095.

The performance values presented are not in satisfactory agreement with the log book or the Rocketdyne J-2 engine manual No. R-3825-1 (0.340 ±0.030 sec and 38,100 ±3,000 lbf-sec, based on a main LOX valve temperature of 0 deg F with PU valve in the null position, and defined from cutoff signal to 5 percent of rated thrust). Stage performance during flight should not be adversely affected by the above conditions.

The deviation in cutoff impulse to 11,250 lbf from Rocketdyne nominal values (which are based on thrust load cell data) was probably caused by a time lag in the chamber pressure measurement from which computer program F839 calculates cutoff impulse. The time lag, which results from the finite time required to vent the chamber pressure transducer during cutoff transient, has averaged approximately 40 ms on previous acceptance firings and is under investigation by the engine manufacturer. The actual cutoff impulse was thus less than that calculated by program F839. Figure 6-26 presents the combustion chamber pressure data for the cutoff transient and the cutoff transient thrust as computed by program F839 for the acceptance and verification firings. Figure 6-27 presents accumulated cutoff impulse from engine cutoff to 11,250 lbf thrust for the acceptance and verification firings.

6.4 Engine Sequencing

The engine sequencing was satisfactory throughout the acceptance firing and compatible with the engine logic and acceptance firing test plan. Figure 6-28 presents the engine start sequence for the acceptance firing; table 6-4 presents the time of significant events during both firings and compares them to the nominal values. During the engine verification firing, the sequence data was invalid. Approximate sequence data was taken from other sources.

An orifice was installed in the gas generator valve control line to delay the opening of the valve by approximately 65 ms thereby eliminating the high line pressure effects on the main LOX valve. Satisfactory results were obtained.

6.5 Component Operation

All of the J-2 engine components performed satisfactorily during the acceptance firing except the LOX turbopump. The first stage turbine wheel rubbed against the stator damaging the stator, the turbine wheel, and the honeycomb seal. Metal particles from the damaged parts caused additional damage to other parts in the turbine. Engines prior to S/N 2060 have a history of LOX turbopump malfunctions. The specification allows 0.025 in. interference between the rotor and the stator. This has been exceeded several times including the S-IVB-206 stage acceptance firing. The problem has been analyzed by the engine manufacturer and the solution has been to use a thicker first stage turbine wheel thereby minimizing wheel flexure and maintaining the proper tolerance. The new turbine wheel will be installed on engine S/N 2060 and subs and any prior engines requiring a replacement. The S-IVB-206 stage turbopump assembly was replaced by one incorporating the thicker turbine wheel, and a 70-sec verification firing was conducted. At present, the best estimate indicates that the malfunction occurred during the early portion of the acceptance firing.

The main LOX valve required 2.65 sec to open. This was satisfactory based on the specified time of 2.110 $\pm$0.150 sec for dry valve operation. The second stage travel was devoid of line pressurization disturbances indicating the effectiveness of the modification to retard the opening of the gas generator valve (paragraph 6-4). The main LOX valve opening time data were as follows:

Parameter	Specification	Dry Valve Checkout	Acceptance Firing
First stage travel (ms)	50 ±20	46	64
Plateau (ms)	460 ±55	496	500
Second stage travel (ms)	1,600 ±75	1,620	2,079
Total (ms)	2,110 ±150	2,162	2,643

TABLE [illegible]-1
COMPARISON OF COMPUTER PROGRAM RESULTS

PROGRAM	INPUT	METHOD	RESULTS	
			ACCEPTANCE FIRING	VERIF FIRING
G105 Mode 3	LOX and LH2 flowmeters, pump discharge pressures and temperatures, chamber pressures, chamber thrust area	Flowrates are computed from flowmeter data and propellant densities. The C_F is determined from equation $C_F = f\ (P_c, MR)$ and thrust is calculated from equation $F = C_F A_t P_c$.	F = 221,869 $\dot{W}_T$ = 524.69 I_{sp} = 422.94 MR = 5.353	226,315 537.40 421.23 5.465
F823 Mode 1	Thrust chamber pressure, gas generator pressure, LH2 injection temperature, LH2 pump discharge temperature, LH2 turbine inlet temperature	Total flows of the thrust chamber and gas generator are calculated as a function of respective chamber pressures. Mixture ratio of the chamber is calculated as a function of temperature rise of the LH2 in the cooling jacket, and mixture ratio of the GG is calculated as a function of turbine inlet temperature. Thrust is calculated from the equation $F = C_F A_t P_c$.	F = 221,813 $\dot{W}_T$ = 524.83 I_{sp} = 422.70 MR = 5.347	226,304 537.8 420.84 5.472
F839	Thrust chamber pressure, chamber throat area	The C_F is computed from equation $C_F = \ (P_c)$ and thrust is computed from equation $F = C_F A_t P_c$. The impulse is determined from integrated thrust.	Refer to paragraphs 6.3.1 and 6.3.3	

TABLE 6-2
ENGINE PERFORMANCE

	ESC +20 TO ESC +60 SEC		RMR		OVERALL		CLOSED PU	
	ACTUAL	PREDICTED	ACTUAL	PREDICTED	ACTUAL	PREDICTED	ACTUAL	PREDICTED
Thrust (lbf)	228,231	228,700	193,415	191,158	221,841	216,404	226,293	228,737
Total Flowrate (lbm/sec)	540.35	540.98	452.93	444.81	524.76	509.47	536.01	541.31
LOX Flowrate (lbm/sec)	457.656	458.384	375.06	367.85	442.18	429.24	452.747	457.899
LH2 Flowrate (lbm/sec)	82.75	82.59	77.91	76.96	82.58	80.638	83.26	82.40
Engine Mixture Ratio	5.53	5.55	4.814	4.78	5.35	5.318	5.438	5.569
Specific Impulse (sec)	422.38	422.75	426.99	429.75	422.82	424.76	422.22	422.56

TABLE 6-3
ENGINE THRUST VARIATIONS

TIME PERIOD	MEAN SLOPE (lbf/sec)			MAXIMUM RATE (lbf/sec)			MAXIMUM AMPLITUDE (lbf) Zero to Peak		
	ALLOWABLE	ACTUAL	PREDICTED	ALLOWABLE	ACTUAL	PREDICTED	ALLOWABLE	ACTUAL	PREDICTED
PU Valve Hardover at 5.5/1.0 EMR	--	--	--	±500	±80	±100	±2500	±700	±750
Valve Cutback +50 sec to ECC -70 sec	--	--	--	±500	DNA	-120	±7500	DNA	±800
ECC -70 sec to ECC	±58	-260	-30	±500	1200	-150	±2000	13,800	±600
ECC -40 sec to ECC		-15			-275			+2,000	

TABLE 6-4 (Sheet 1 of 5)
ENGINE SEQUENCE

CONTROL EVENTS		CONTINGENT EVENTS		SPECIFIED AND NOMINAL TIMES	TIME FROM ESC (ms)	
MEAS NO.	EVENT AND COMMENT	MEAS NO.	EVENT AND COMMENT		ACCEPT FIRING	ENGINE VERIF FIRING
K0021	*Engine Start Command P/U			0	0	0
		K0007	Helium Control Solenoid Enrg P/U	Within 10 ms of K0021	0	0
		K0010	Thrust Chamber Spark on P/U	Within 10 ms of K0021	0	0
		K0011	Gas Generator Spark on P/U	Within 10 ms of K0021	0	0
		K0006	Ignition Phase Control Solenoid Enrg P/U	Within 20 ms of K0021	6	10
		K0012	Engine Ready D/O	Within 20 ms of K0006	0	0
		K0126	LOX Bleed Valve Closed P/U	Within 130 ms of K0007	54	70
		K0127	LH2 Bleed Valve Closed P/U	Within 130 ms of K0007	39	50
		K0020	ASI LOX Valve Open P/U	Within 20 ms of K0006	12	20
		K0119	Main Fuel Valve Closed D/O	60 $\pm$30 ms from K0006	41	DNA
		K0118	Main Fuel Valve Open P/U	80 $\pm$50 ms from K0119	133	DNA
K0008	**Ignition Detected			Within 250 ms of K0021 P/U	219	140

D/O - Dropout P/U - Pickup DNA - Data not available

* Engine ready and stage separation signals (or simulation) are required before this command will be executed. This command also actuates a 640 $\pm$30 ms timer which controls energizing of the start tank discharge solenoid N010 (K0096)

** This signal must be received within 1,110 $\pm$60 ms of K0021 P/U or cutoff will be initiated.

TABLE 6-4 (Sheet 2 of 5)
ENGINE SEQUENCE

CONTROL EVENTS		CONTINGENT EVENTS		SPECIFIED AND NOMINAL TIMES	TIME FROM ESC (ms)	
MEAS NO.	EVENT AND COMMENT	MEAS NO.	EVENT AND COMMENT		ACCEPT FIRING	ENGINE VERIF FIRING
K0021	*Engine Start Command D/O			Approx 500 ms from K0021 P/U	602	600
K0096	**Start Tank Disc Solenoid Enrg			640 ±30 ms from K0021	643	640
		K0123	Start Tank Disc Valve Closed D/O	100 ±20 ms from K0096	764	760
		K0122	Start Tank Disc Valve Open P/U	100 ±20 ms from K0123	895	850
K0005	Mainstage Control Solenoid Enrg			450 ±30 ms from K0096	1,080	1,080
		K0096	Start Tank Disc Control Solenoid Enrg D/O	450 ±30 ms from K0096	1,082	1,080
		K0121	Main LOX Valve Closed D/O	60 ±20 ms from K0005	1,140	DNA
		K0116	Gas Generator Valve Closed D/O	85 ±25 ms from K0005	1,164	DNA
		K0122	Start Tank Disc Valve Open D/O	95 ±20 ms from K0096	1,173	DNA
		K0117	Gas Generator Valve Open P/U	30 ±15 ms from K0116	1,325	DNA
		K0124	LOX Turbine Bypass Valve Open D/O	Within 100 ms of K0121	1,291	DNA

D/O - Dropout P/U - Pickup DNA - Data not available

* This signal drops out after a time sufficient to lock in the engine electrical.

** An indication of fuel injection temperature of -150 ±40 deg F (or simulation) is required before this command will be executed. This command also actuates a 450 ±30 ms timer which controls the start of mainstage.

TABLE 6-4 (Sheet 3 of 5)
ENGINE SEQUENCE

CONTROL EVENTS		CONTINGENT EVENTS		SPECIFIED AND NOMINAL TIMES	TIME FROM ESC (ms)	
MEAS NO.	EVENT AND COMMENT	MEAS NO.	EVENT AND COMMENT		ACCEPT FIRING	ENGINE VERIF FIRING
		K0124	LOX Turbine Bypass Valve 80% closed	400 $^{+150}_{-50}$ ms from K0122	1,528	DNA
		K0123	Start Tank Disc Valve Closed P/U	250 $\pm$40 ms from K0122	1,438	DNA
		K0125	*LOX Turbine Bypass Valve Closed P/U		1,588	DNA
K0158	Mainstage Press Switch No. 1 Depress D/O				2,632	2,590
K0159	Mainstage Press Switch No. 2 Depress D/O				2,623	2,090
K0191	**Mainstage OK				2,626	2,090
		K0120	Main LOX Valve Open P/U	2,125 $\pm$150 ms from K0005	3,783	
		K0010	Thrust Chamber Spark on D/O	4,390 $\pm$260 ms from K0010 P/U	4,367	4,370
		K0011	Gas Generator Spark on D/O	4,390 $\pm$260 ms from K0011 P/U	4,365	4,360
K0507 CSS-22	PU Activate Switch P/U				6,276	6,250
					Time from ECC (ms)	
K0013	Engine Cutoff P/U (New time reference)			0	0	0

D/O - Dropout   P/U - Pickup   DNA - Data not available

* Within 5,000 ms of K0005 (Normally = 500 ms)

** One of these signals must be received within 4,410 $\pm$260 ms from K0021 P/U, or cutoff will be initiated. Signal occurs when LOX injection pressure is 500 $\pm$30 psig.

TABLE 6-4 (Sheet 4 of 5)
ENGINE SEQUENCE

CONTROL EVENTS		CONTINGENT EVENTS		SPECIFIED AND NOMINAL TIMES	TIME FROM ESC (ms)	
MEAS NO.	EVENT AND COMMENT	MEAS NO.	EVENT AND COMMENT		ACCEPT FIRING	ENGINE VERIF FIRING
		K0005	Mainstage Control Solenoid Enrg D/O	Within 10 ms of K0013	20	21
		K0006	Ignition Phase Control Solenoid Enrg D/O	Within 10 ms of K0013	19	19
		K0020	ASI LOX Valve Open D/O		23	22
		K0120	Main Oxidizer Valve Open D/O	60 ±15 ms from K0005	66	DNA
		K0117	Gas Generator Valve Open D/O	100 ±30 ms from K0006	92	DNA
		K0118	Main Fuel Valve Open D/O	90 ±25 ms from K0006	91	DNA
		K0121	Main Oxidizer Valve Closed P/U	120 ±15 ms from K0120	272	DNA
		K0116	Gas Generator Valve Closed P/U	500 ms from K0006	184	DNA
		K0119	Main Fuel Valve ClosedPU	225 ±25 ms from K0118	365	DNA
K0158	*Mainstage Press Switch A Depress P/U			*	200	231
K0159	Mainstage Press Switch B Depress P/U			*	198	230
K0191	Mainstage OK D/O			*	202	233
K0007	Helium Control Solenoid Enrg D/O			1,000 ±110 ms from K0013	974	977

D/O - Dropout P/U - Pickup DNA - Data not available

* Signal drops out when pressure reaches 425 ±25 psig.

TABLE 6-4 (Sheet 5 of 5)
ENGINE SEQUENCE

CONTROL EVENTS		CONTINGENT EVENTS		SPECIFIED AND NOMINAL TIMES	TIME FROM ESC (ms)	
MEAS NO.	EVENT AND COMMENT	MEAS NO.	EVENT AND COMMENT		ACCEPT FIRING	ENGINE VERIF FIRING
SS-22 K0507	PU Activate Switch D/O			N/A	3,260	3,100
		K0125	Oxidizer Turbine Bypass Valve Closed D/O	8,000 ms from K0005	237	DNA
		K0124	Oxidizer Turbine Bypass Valve Open P/U	10,000 ms from K0005	897	DNA
K0126	LOX Bleed Valve Closed D/O			15,000 ms from K0005	2,812	2,846
K0127	LH2 Bleed Valve Closed D/O			15,000 ms from K0005	2,642	3,026

D/O - Dropout P/U Pickup DNA - Data not available

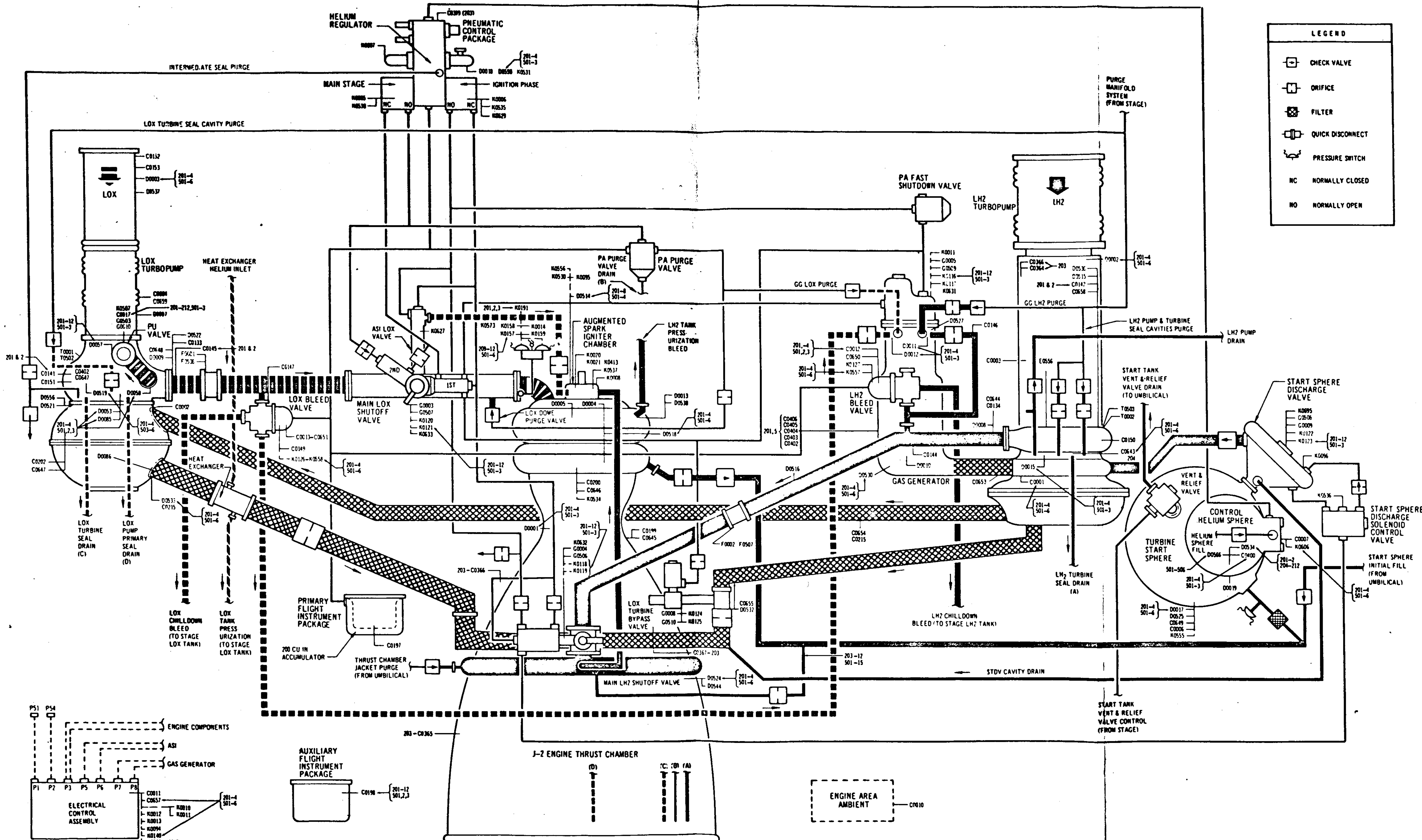


Figure 6-1. J-2 Engine System and Instrumentation

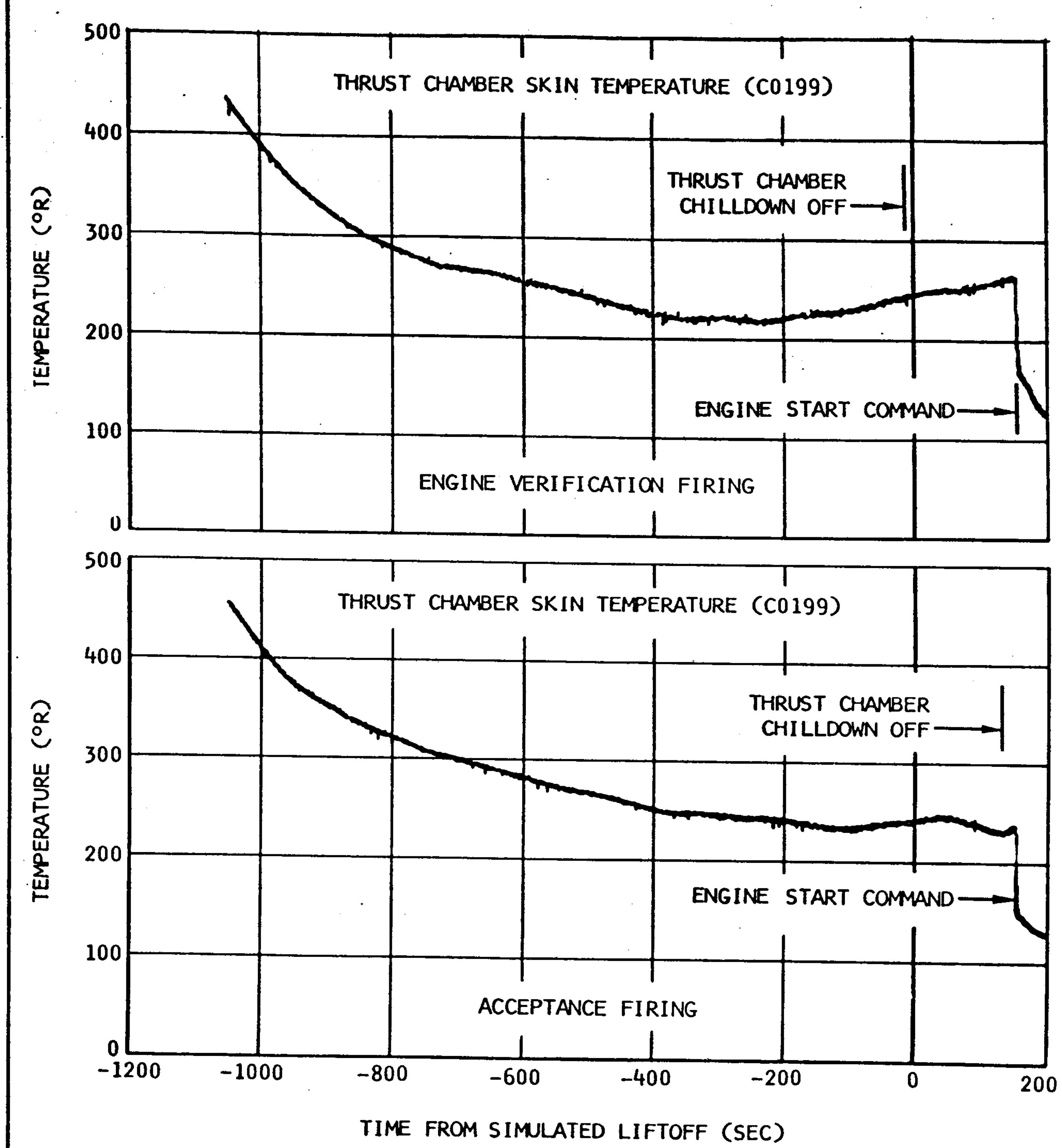


Figure 6-2. Thrust Chamber Childown

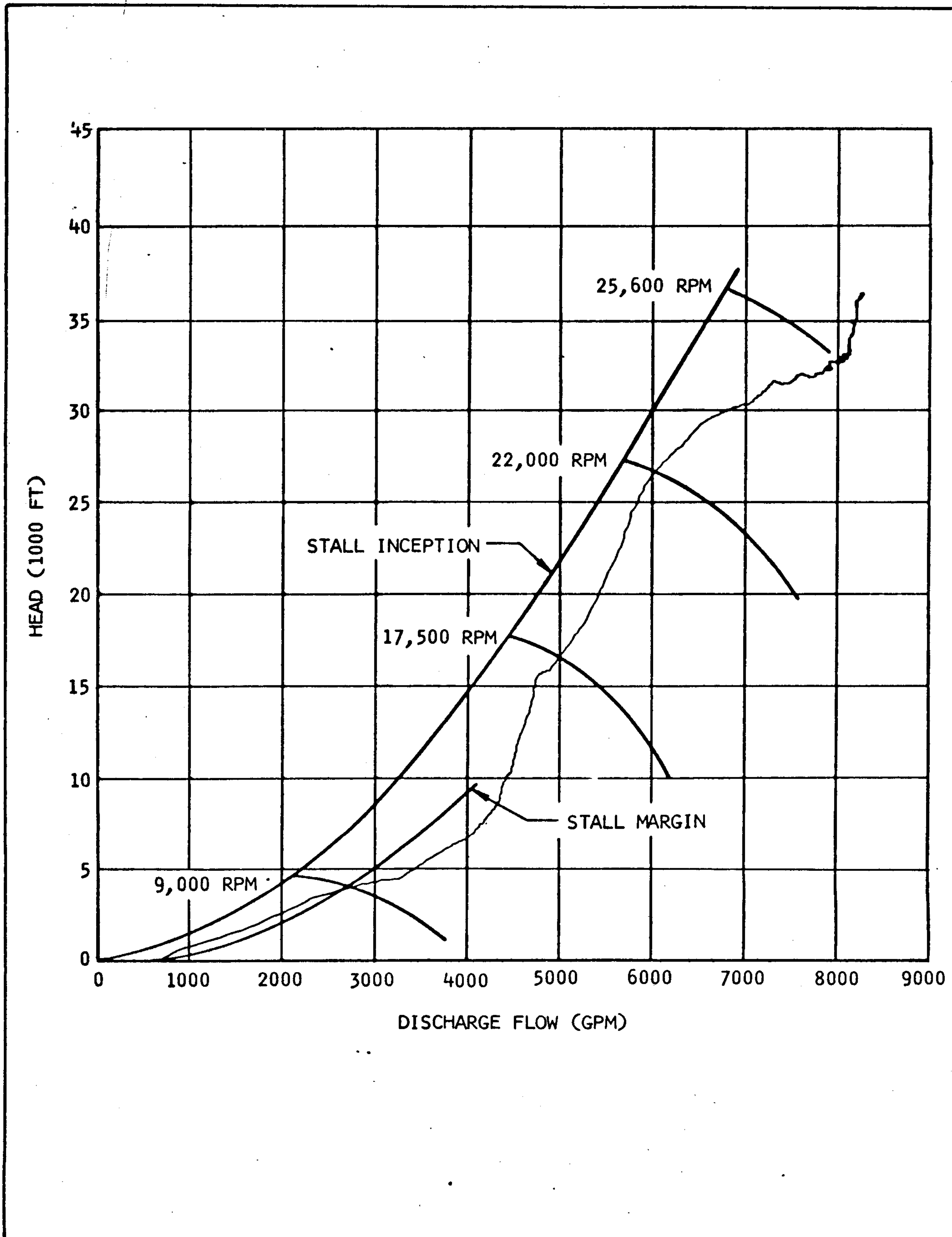


Figure 6-3. LH2 Pump Performance During Engine Start -- Acceptance Firing

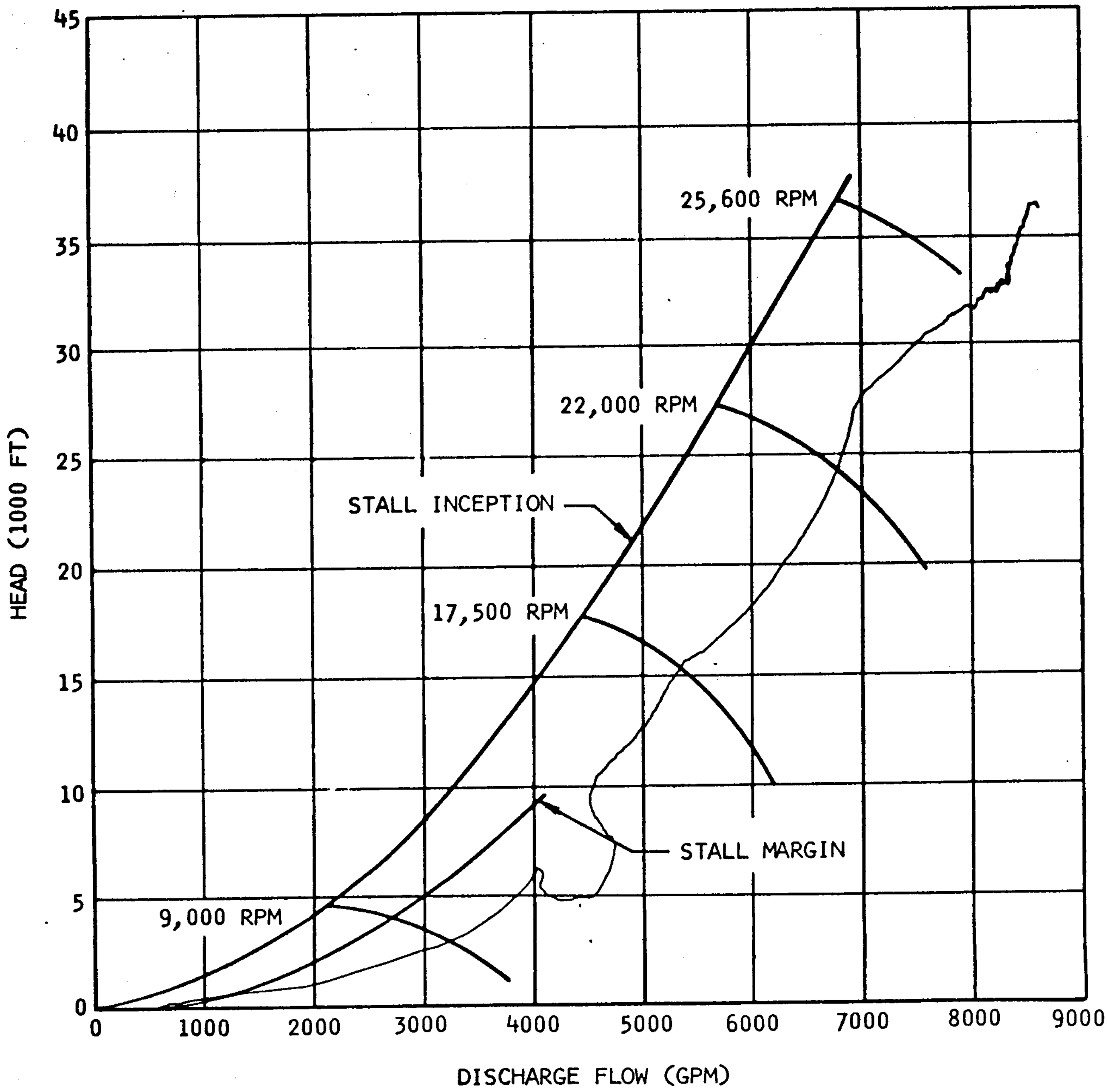


Figure 6-4. LH2 Pump Performance During Engine Start -- Verification Firing

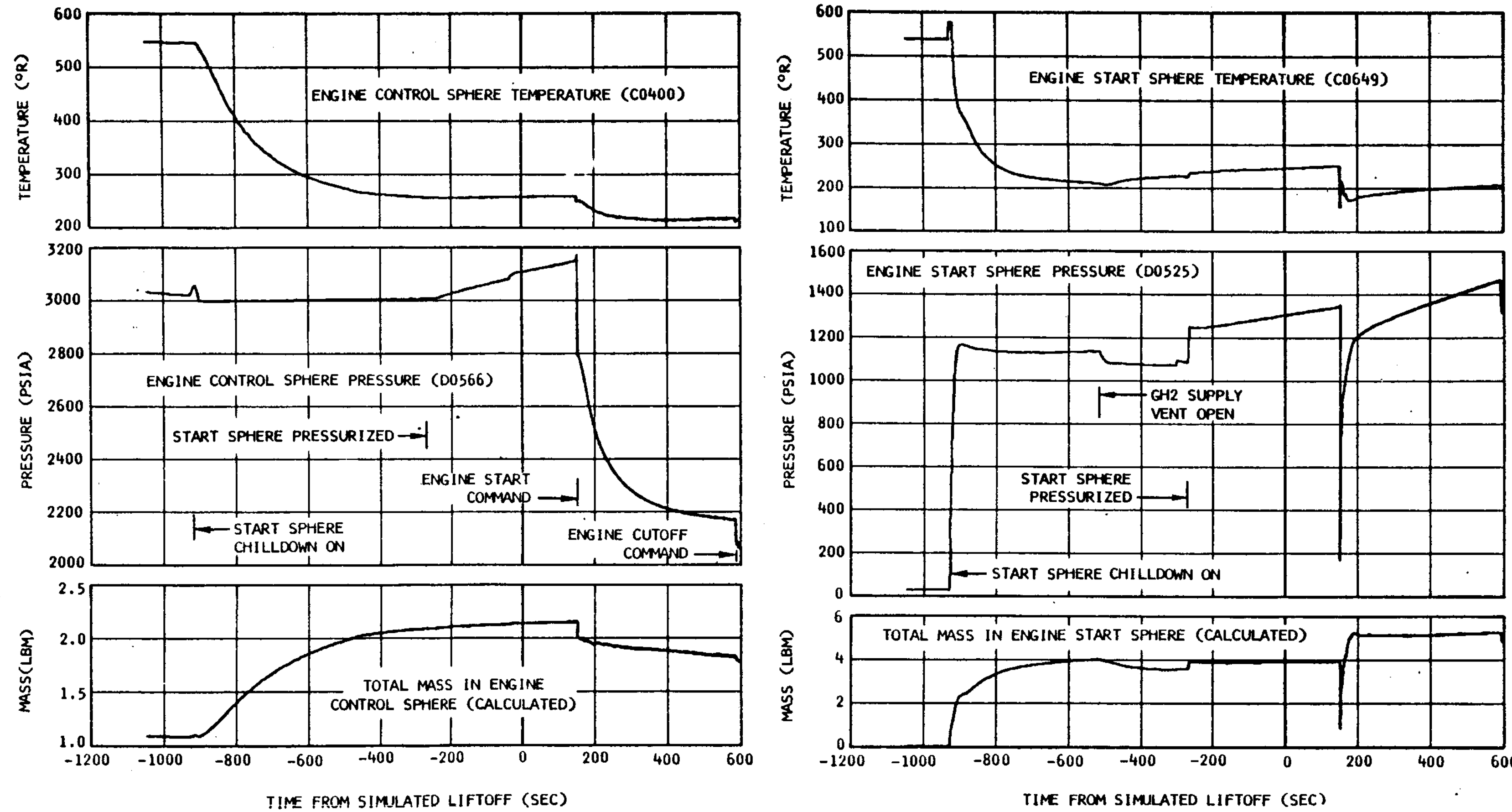


Figure 6-5. Engine Start and Control Sphere Performance

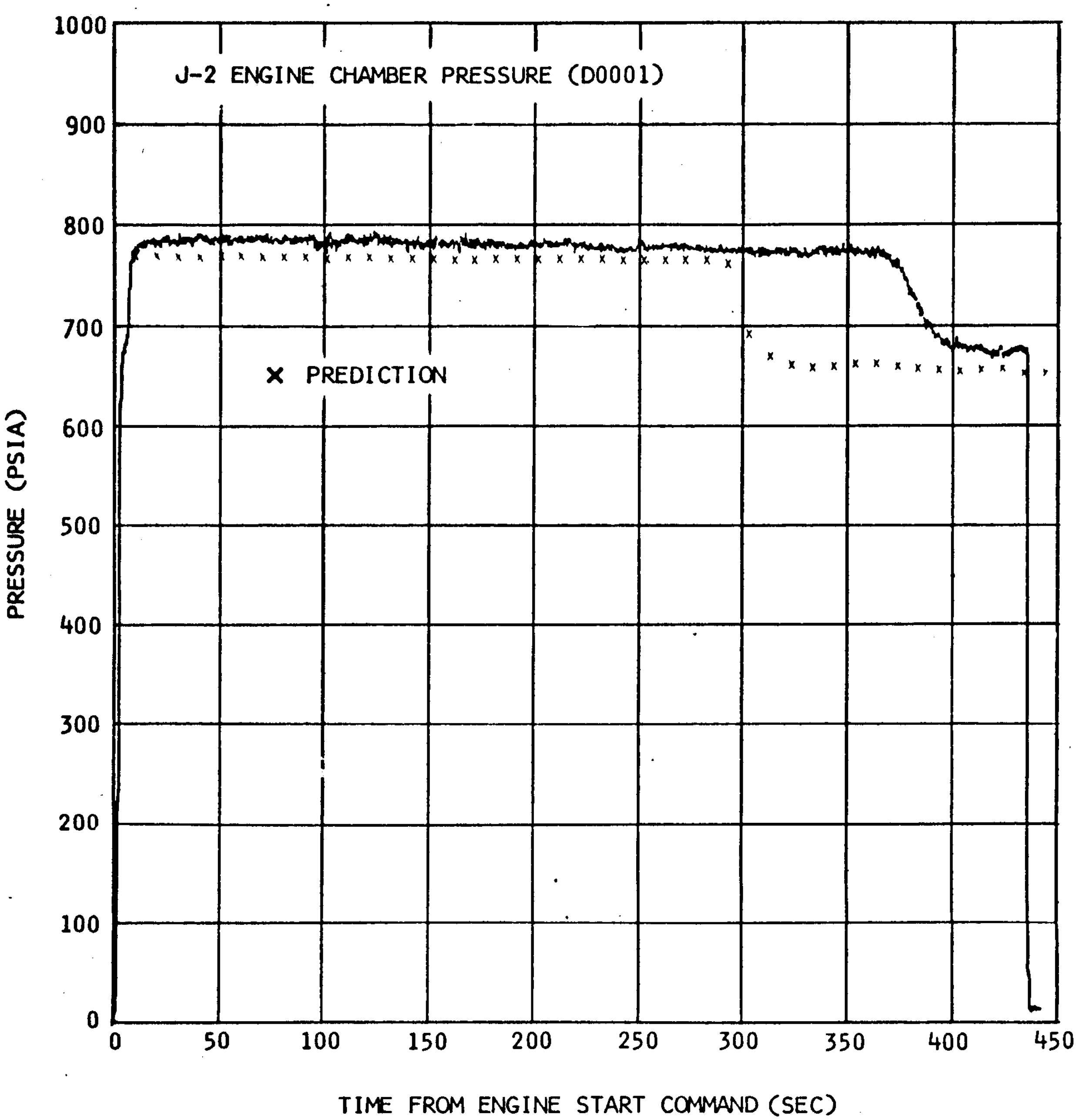


Figure 6-6. J-2 Engine Chamber Pressure -- Acceptance Firing

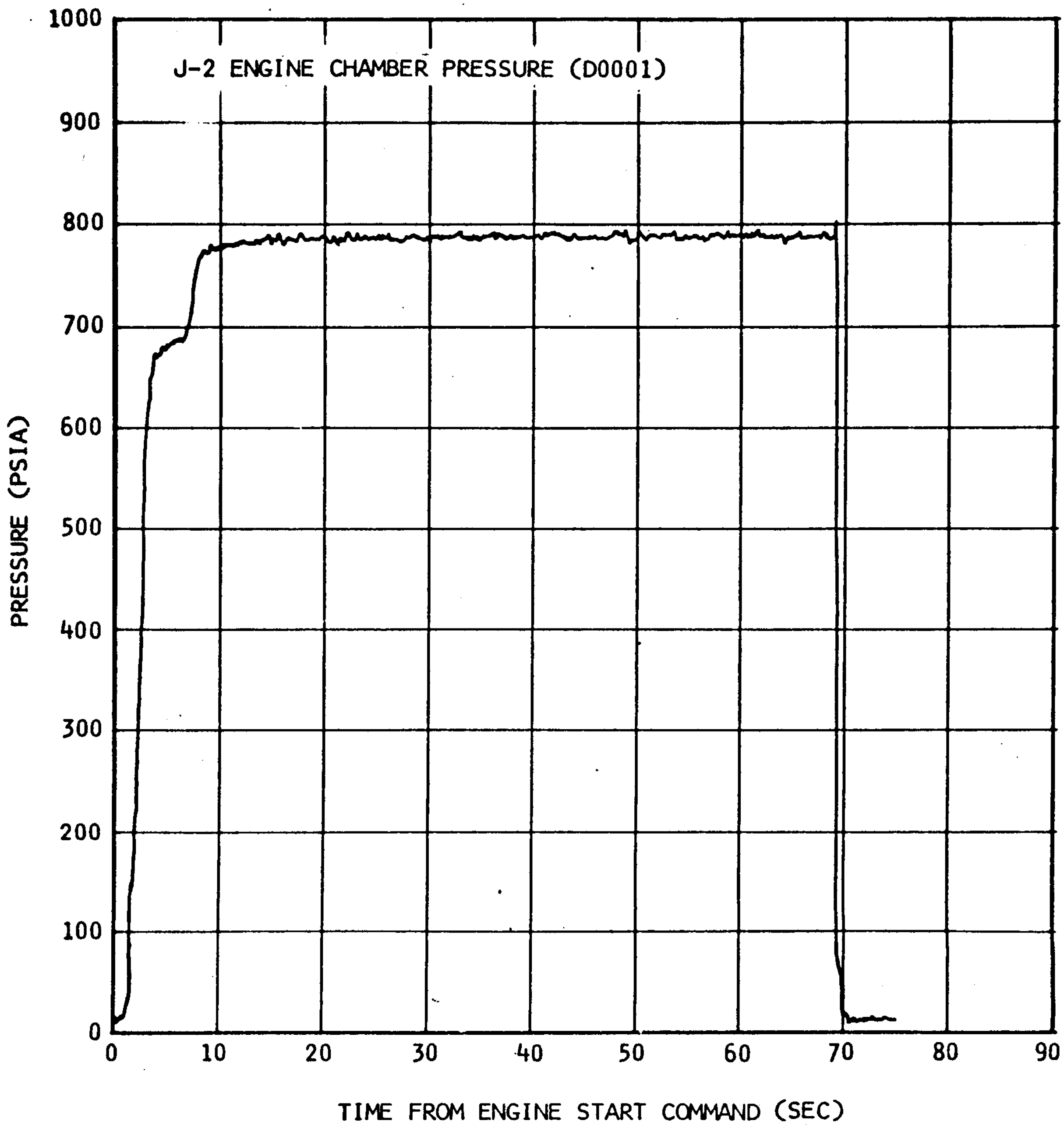


Figure 6-7. J-2 Engine Chamber Pressure -- Verification Firing

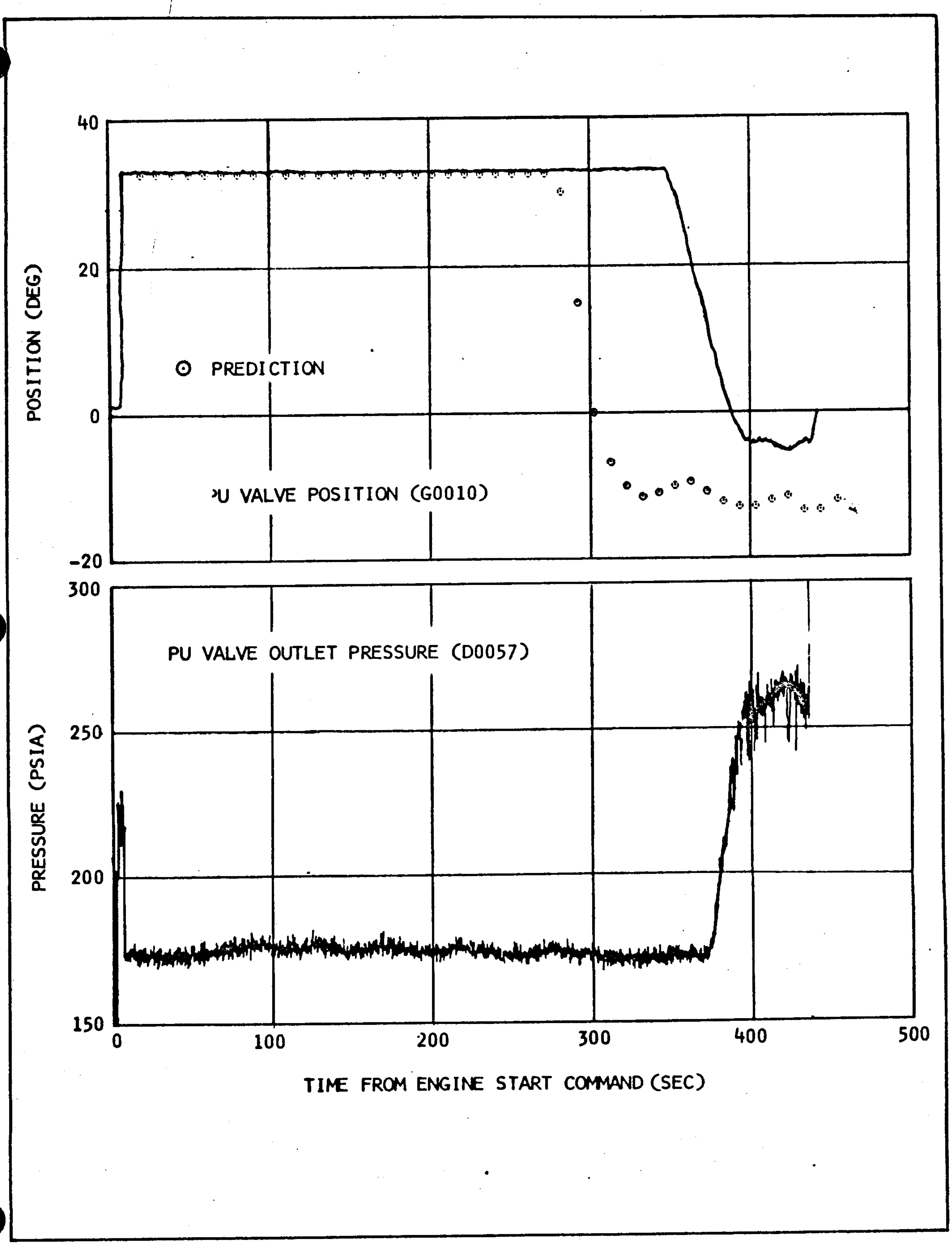


Figure 6-8. PU Valve Operation -- Acceptance Firing

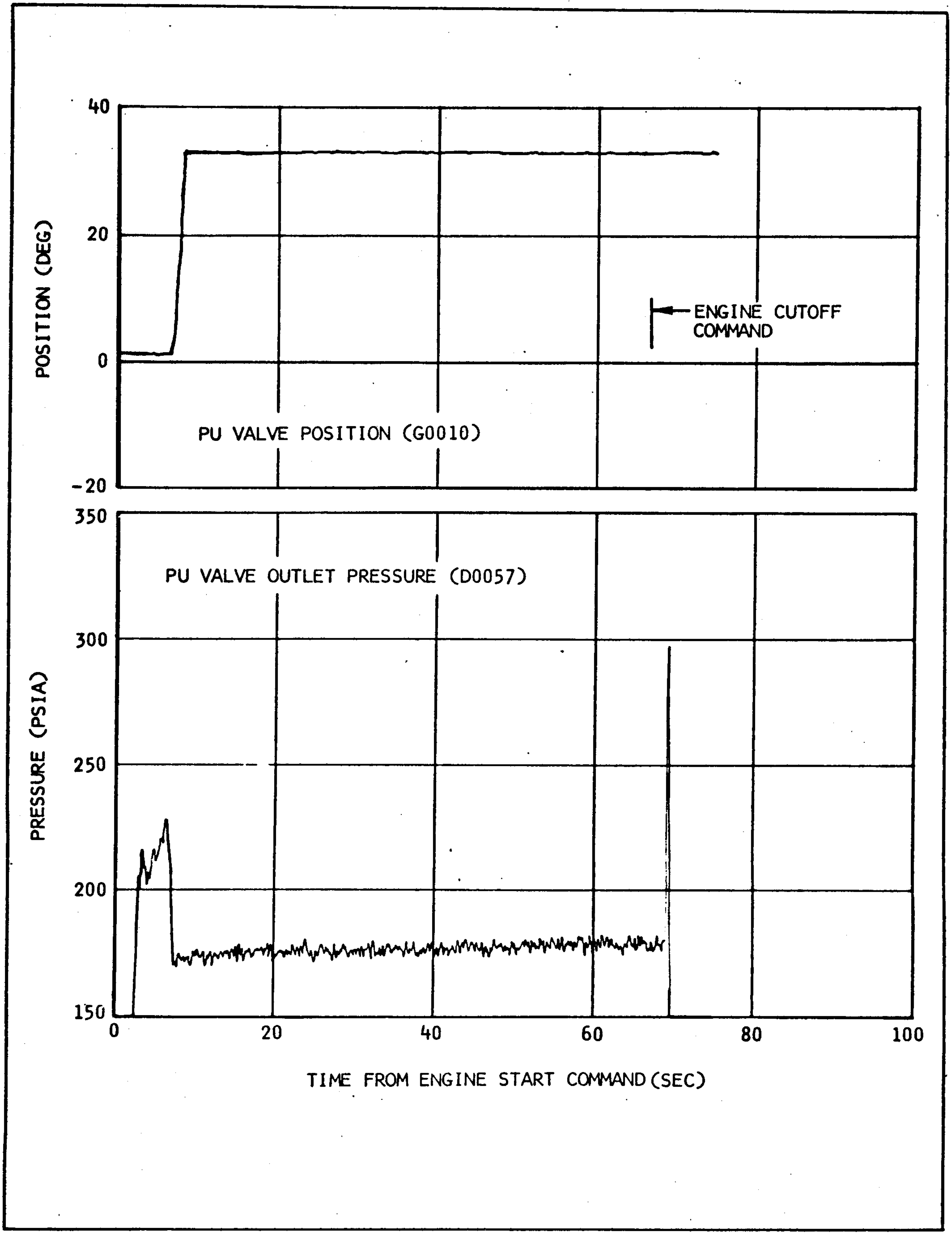


Figure 6-9. PU Valve Operation -- Verification Firing

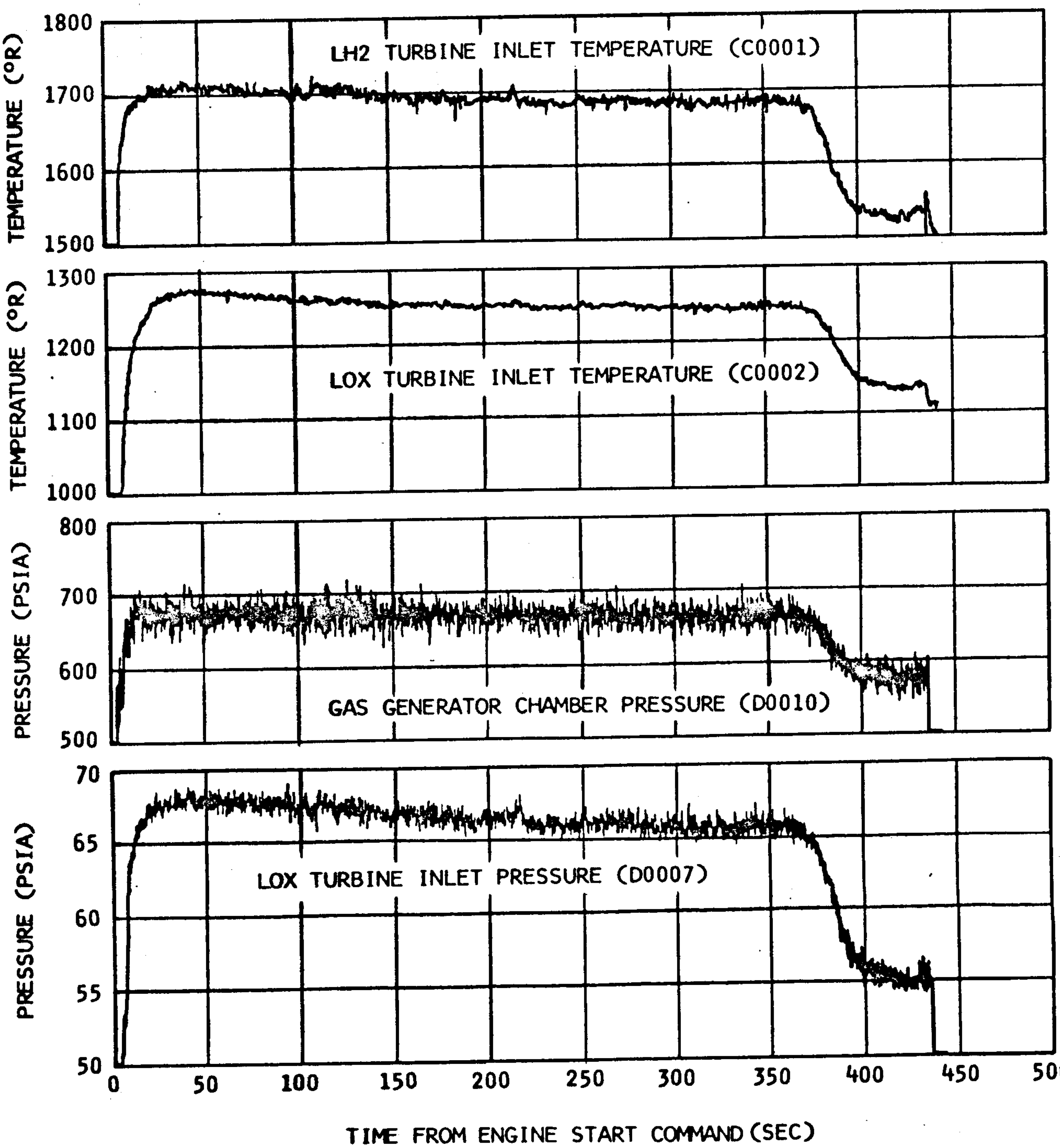


Figure 6-10. Turbine Inlet Operating Conditions -- Acceptance Firing

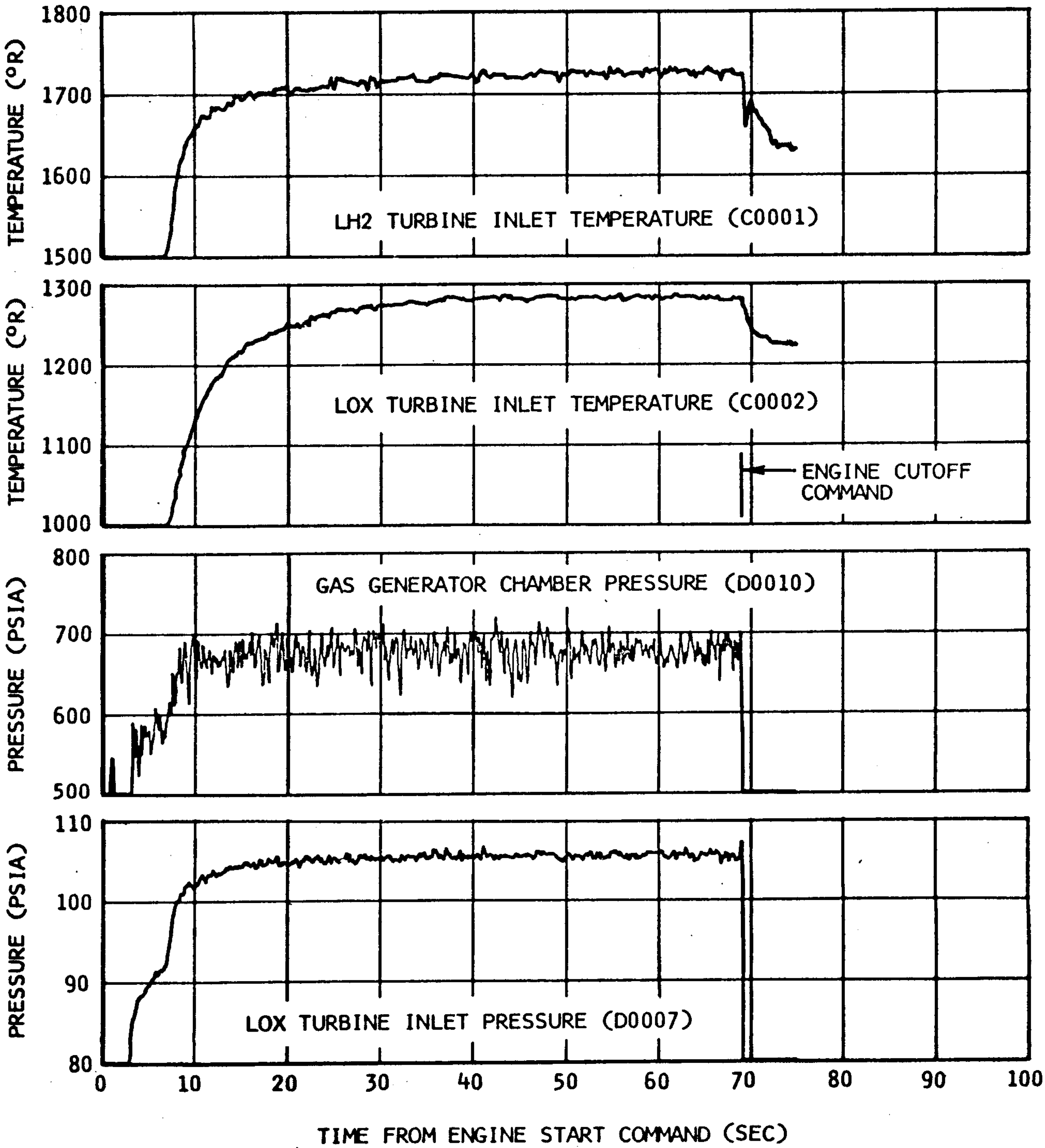


Figure 6-11. Turbine Inlet Operating Conditions -- Verification Firing

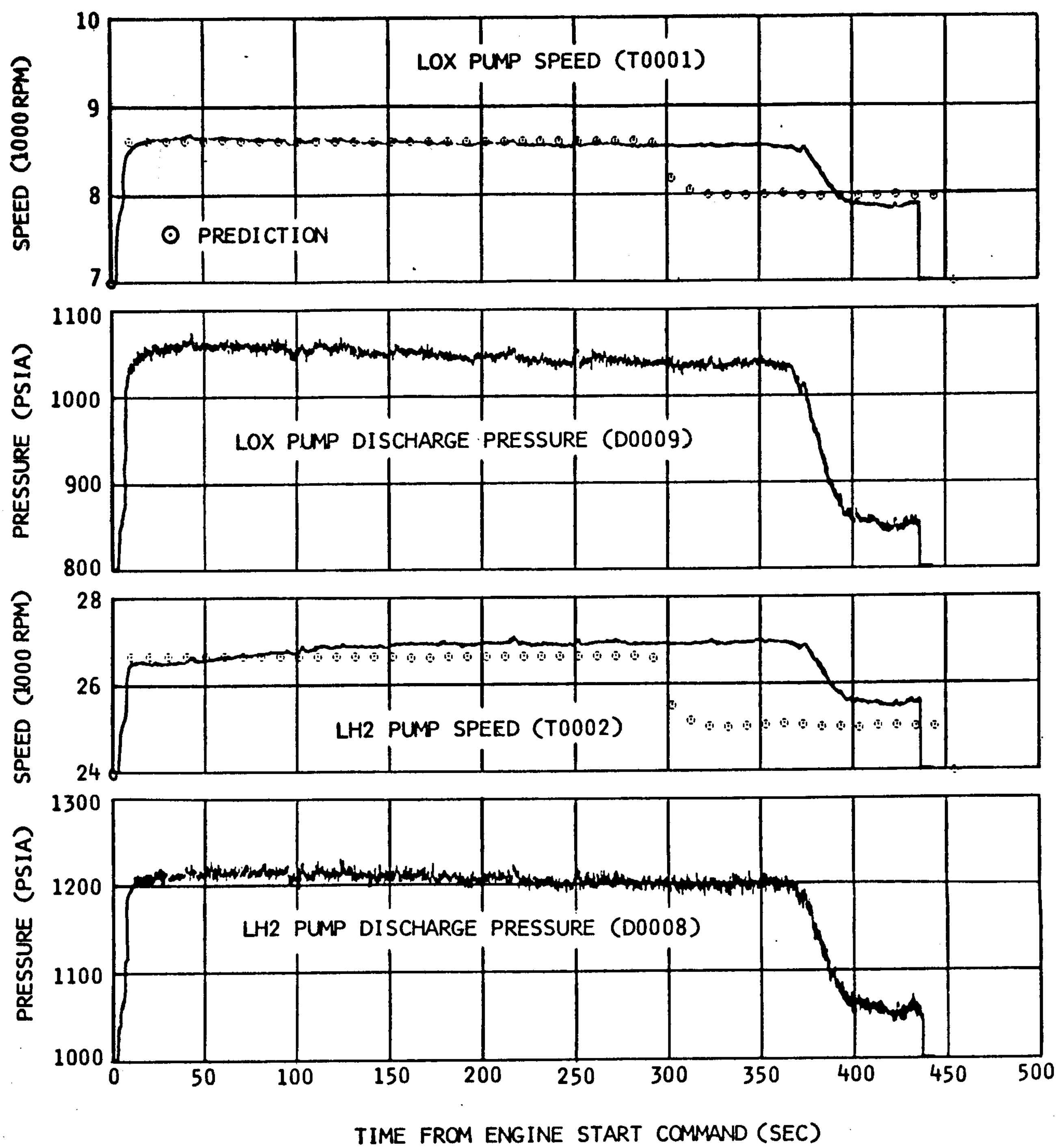


Figure 6-12. J-2 Engine Pump Operating Characteristics -- Acceptance Firing

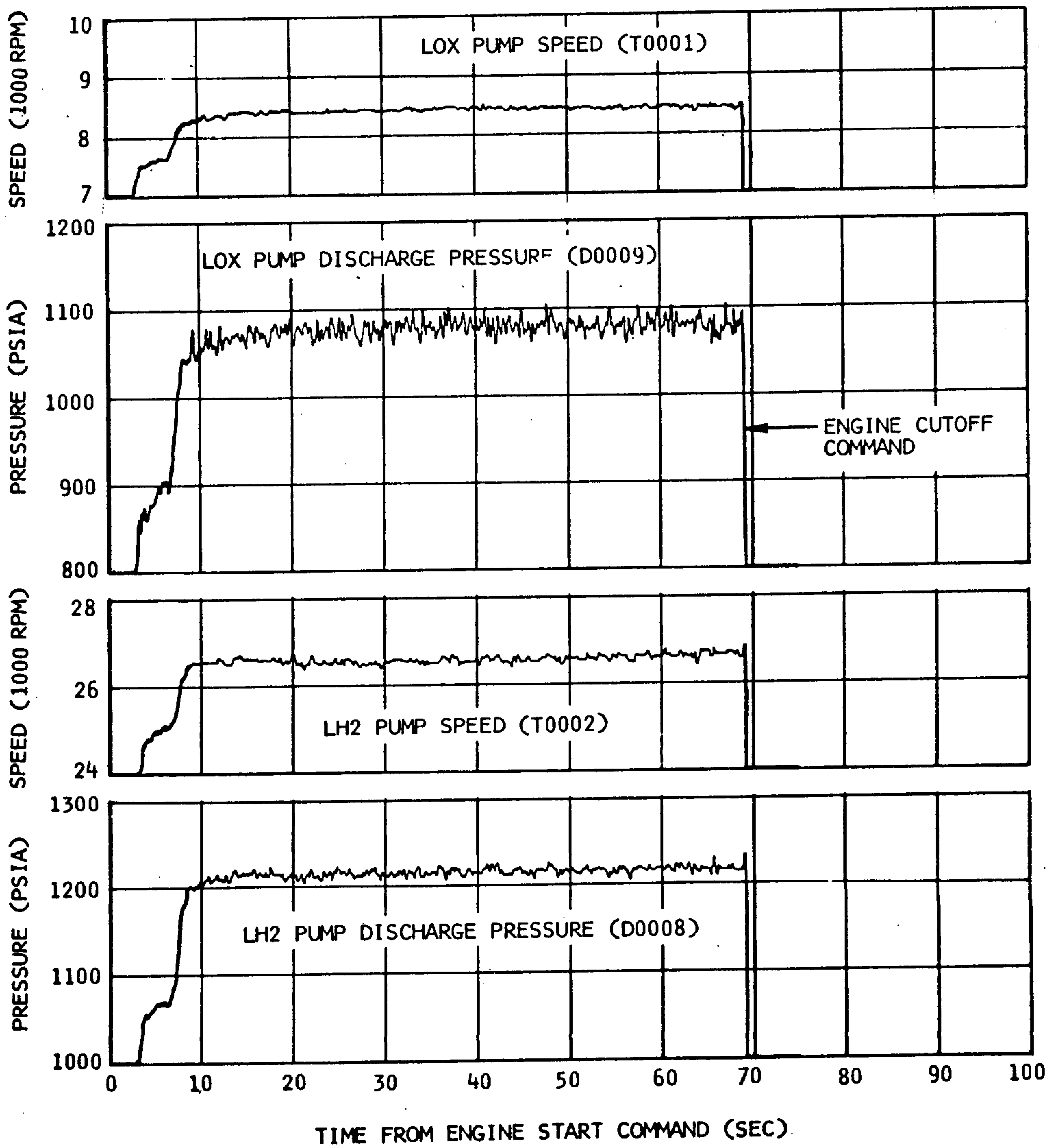


Figure 6-13. J-2 Engine Pump Operating Characteristics -- Verification Firing

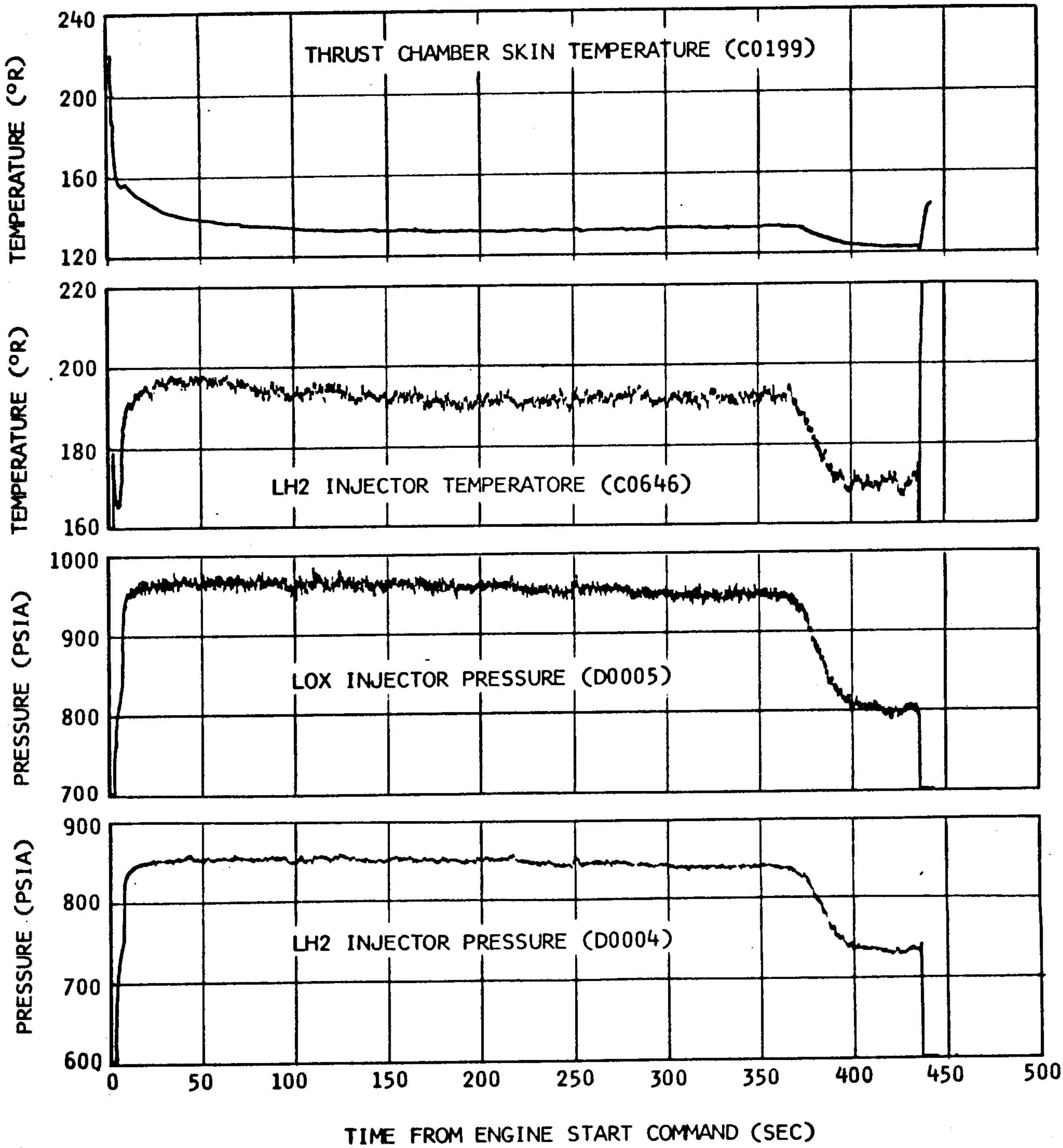


Figure 6-14. J-2 Engine Injector Supply Conditions -- Acceptance Firing

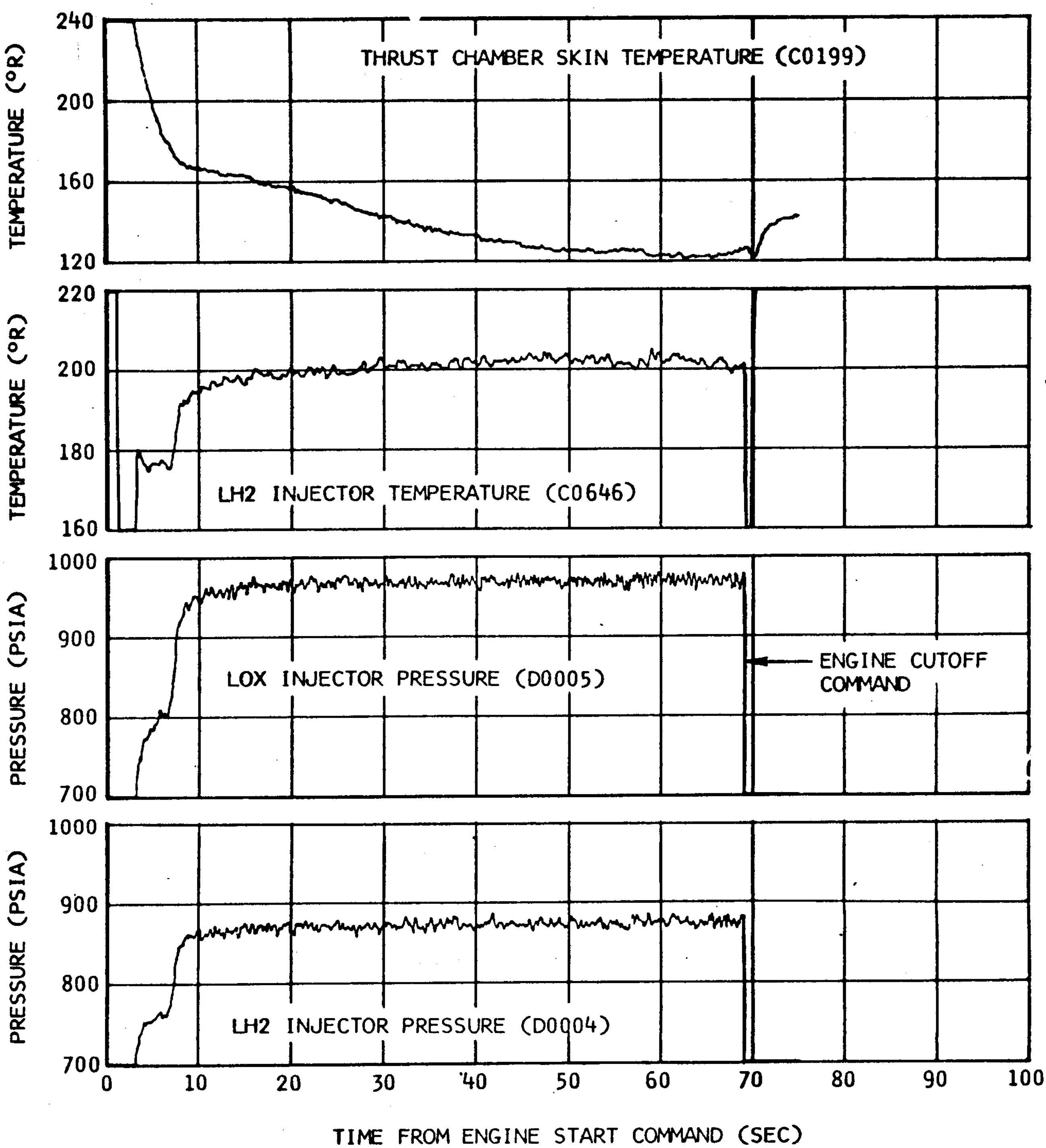


Figure 6-15. J-2 Engine Injector Supply Conditions -- Verification Firing

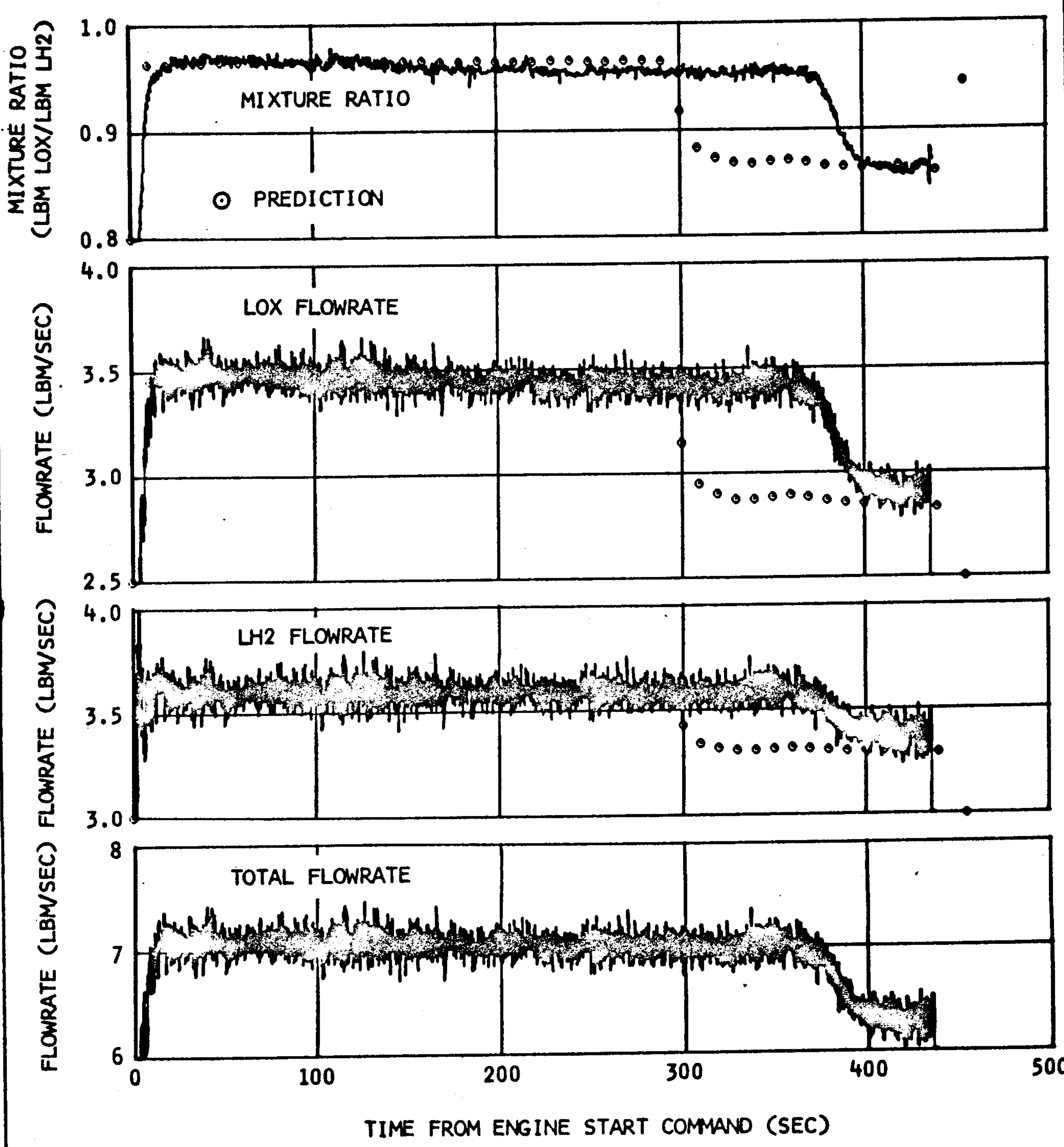


Figure 6-16. Gas Generator Performance -- Acceptance Firing

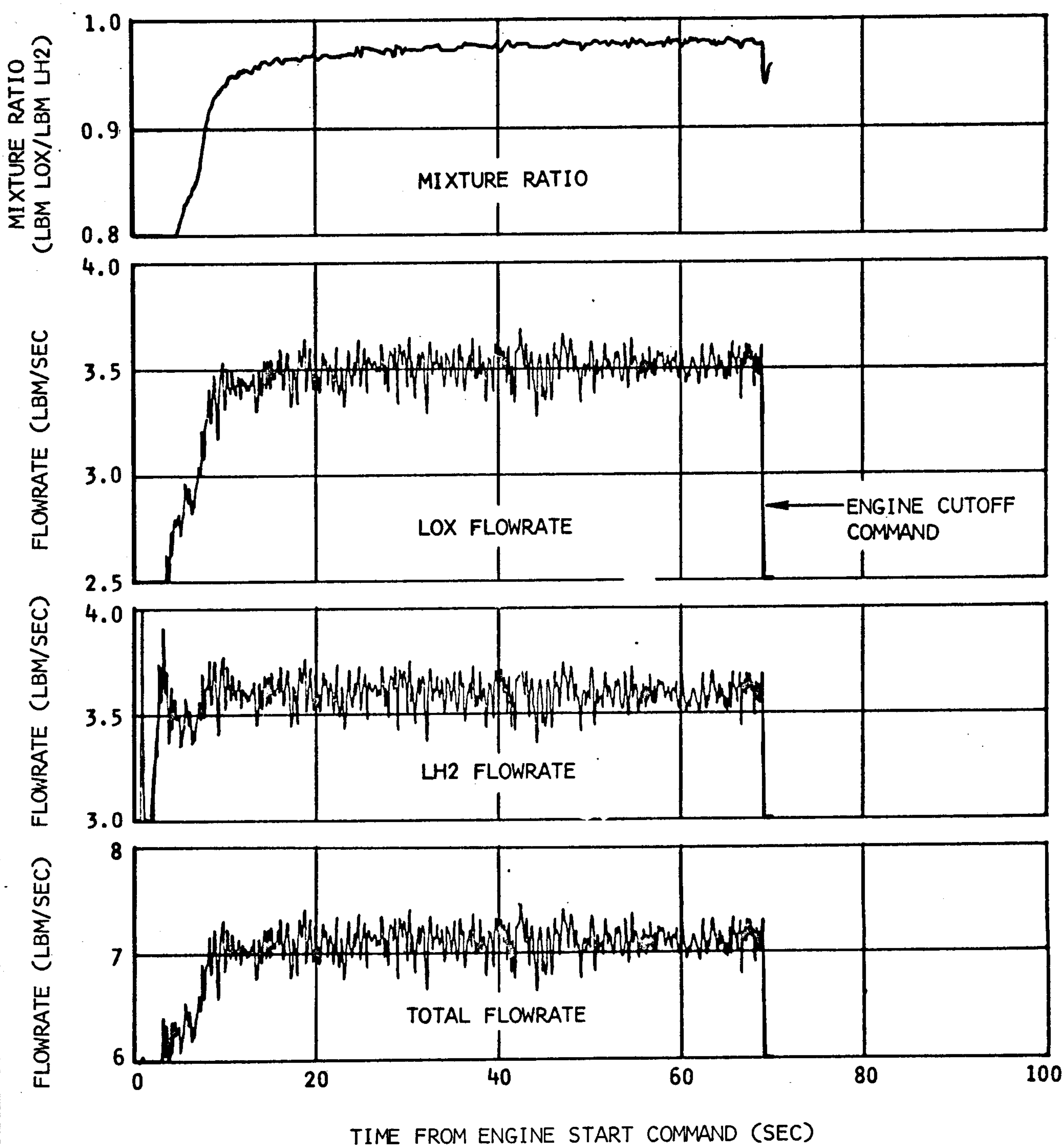


Figure 6-17. Gas Generator Performance -- Verification Firing

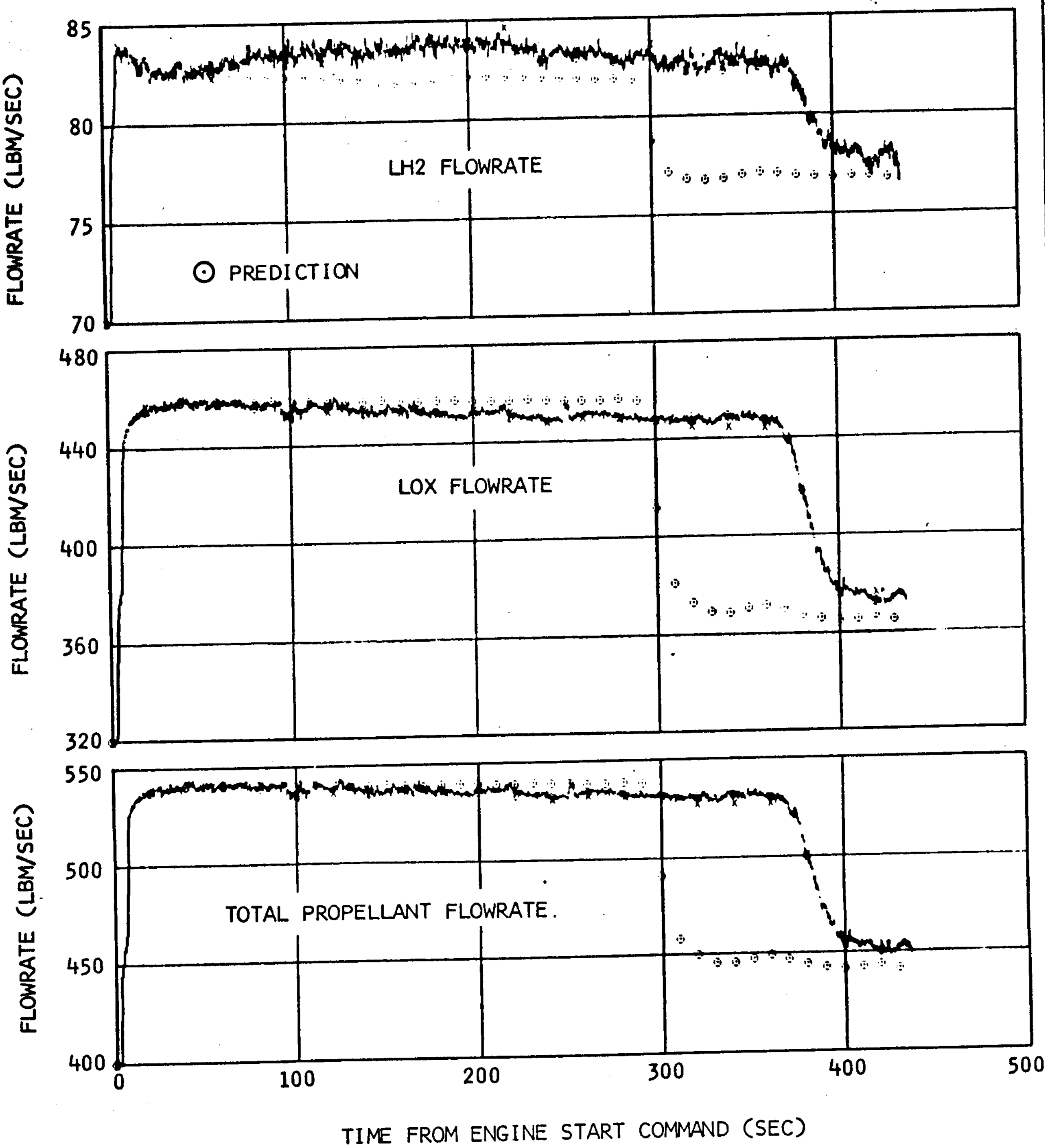


Figure 6-18. Engine Steady-State Performance -- Acceptance Firing (Sheet 1 of 2)

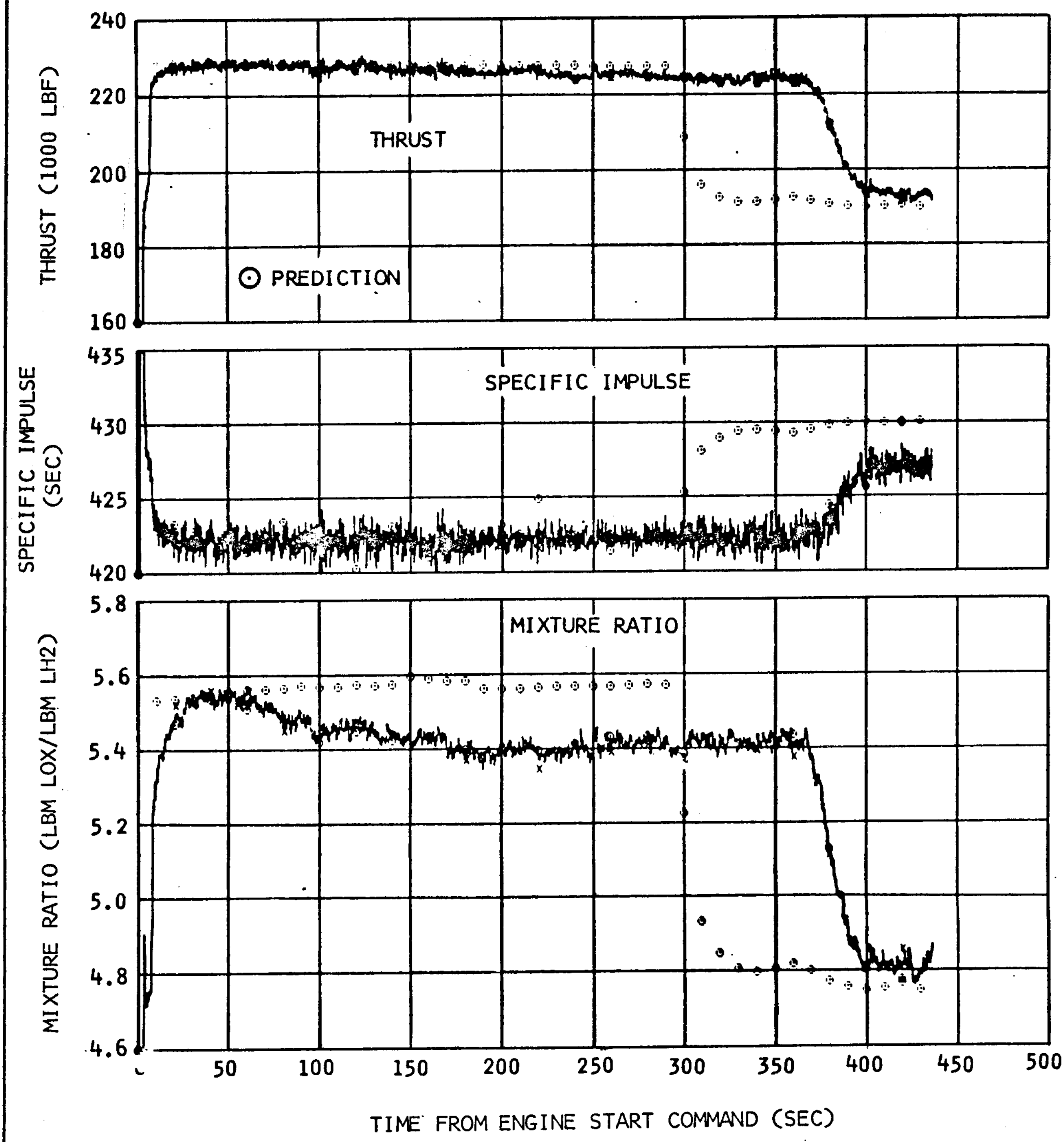


Figure 6-18. Engine Steady State Performance -- Acceptance Firing (Sheet 2 of 2)

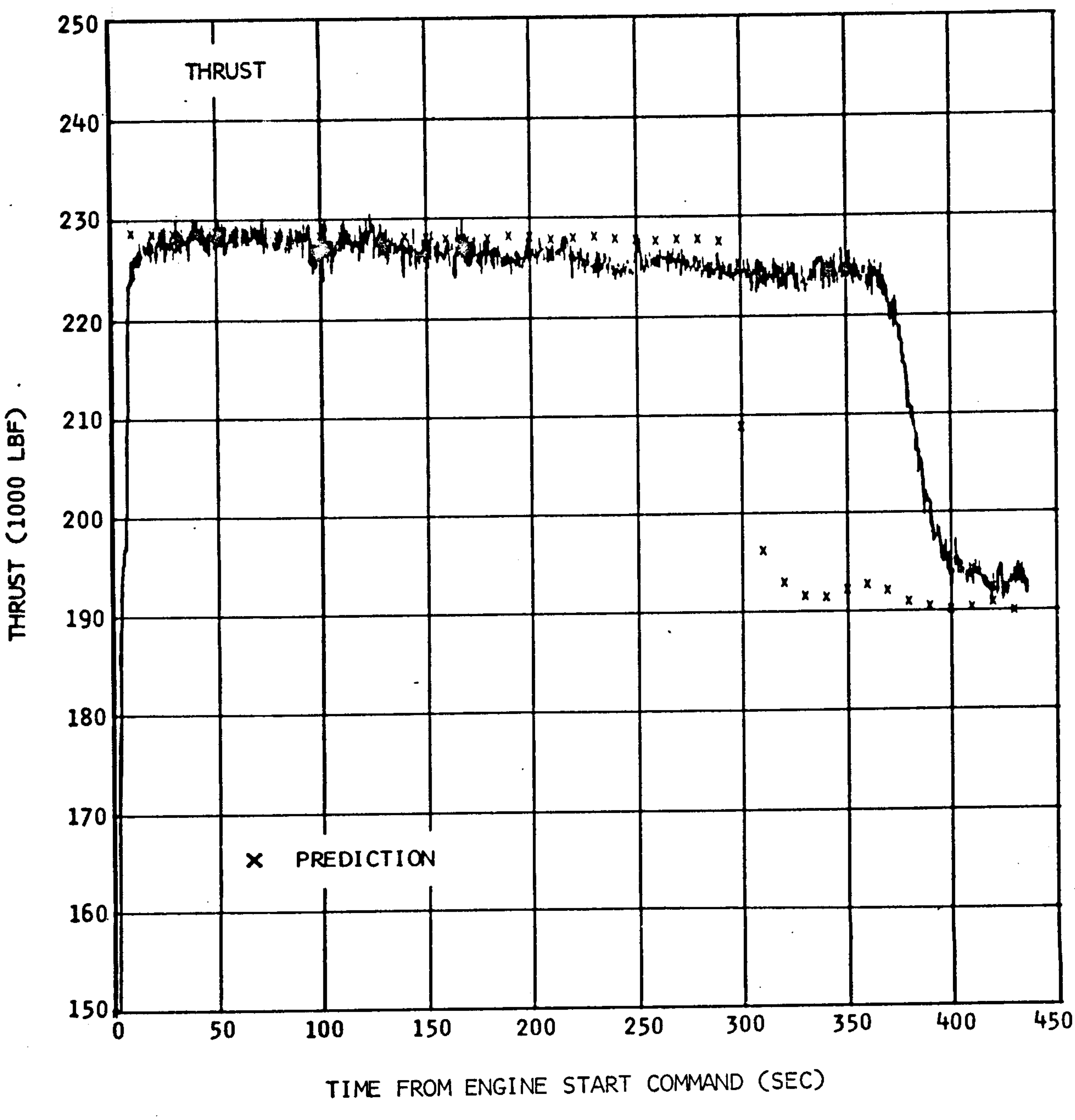


Figure 6-19. J-2 Engine Thrust History -- Acceptance Firing

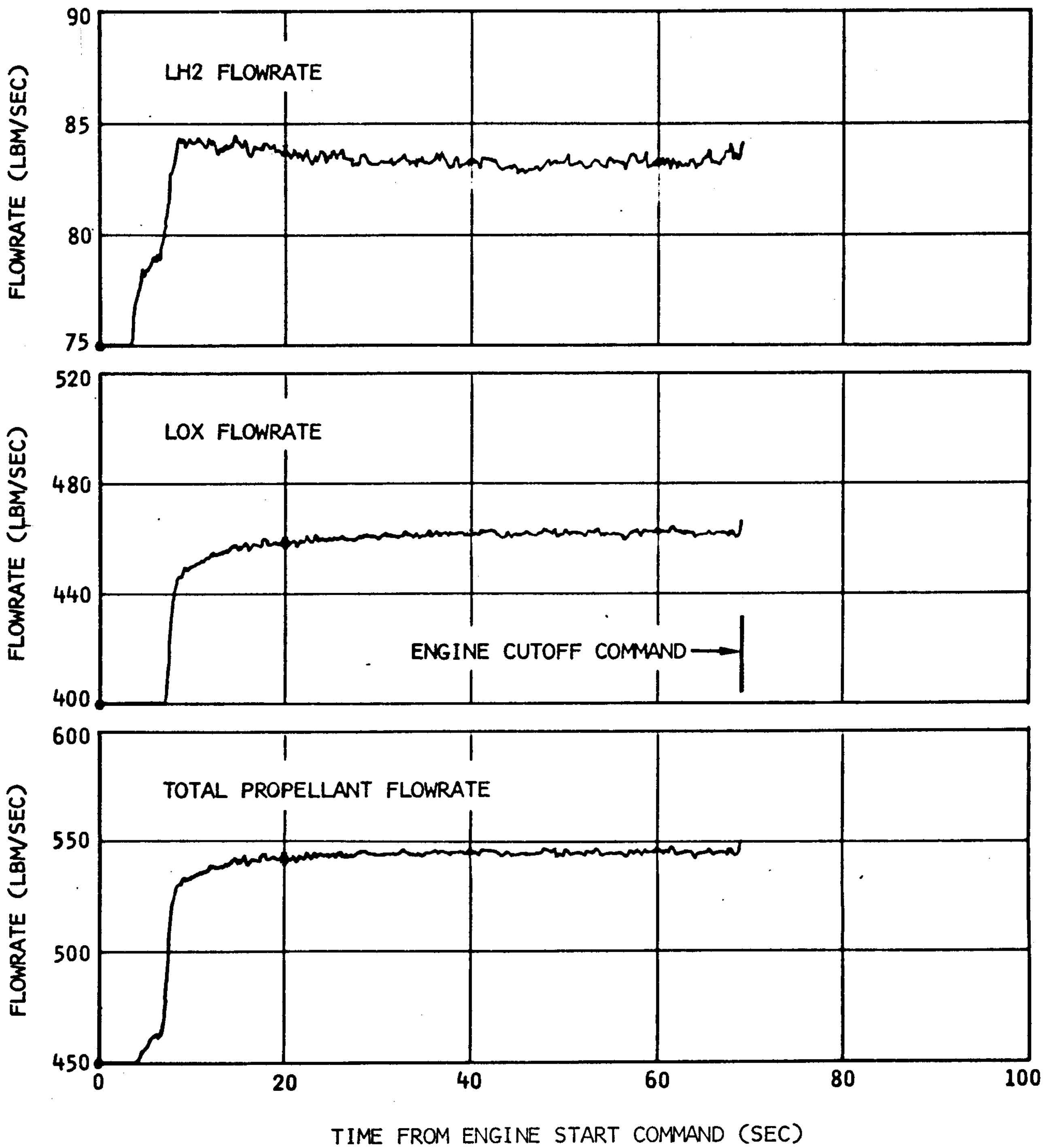


Figure 6-20. Engine Steady-State Performance -- Verification Firing (Sheet 1 of 2)

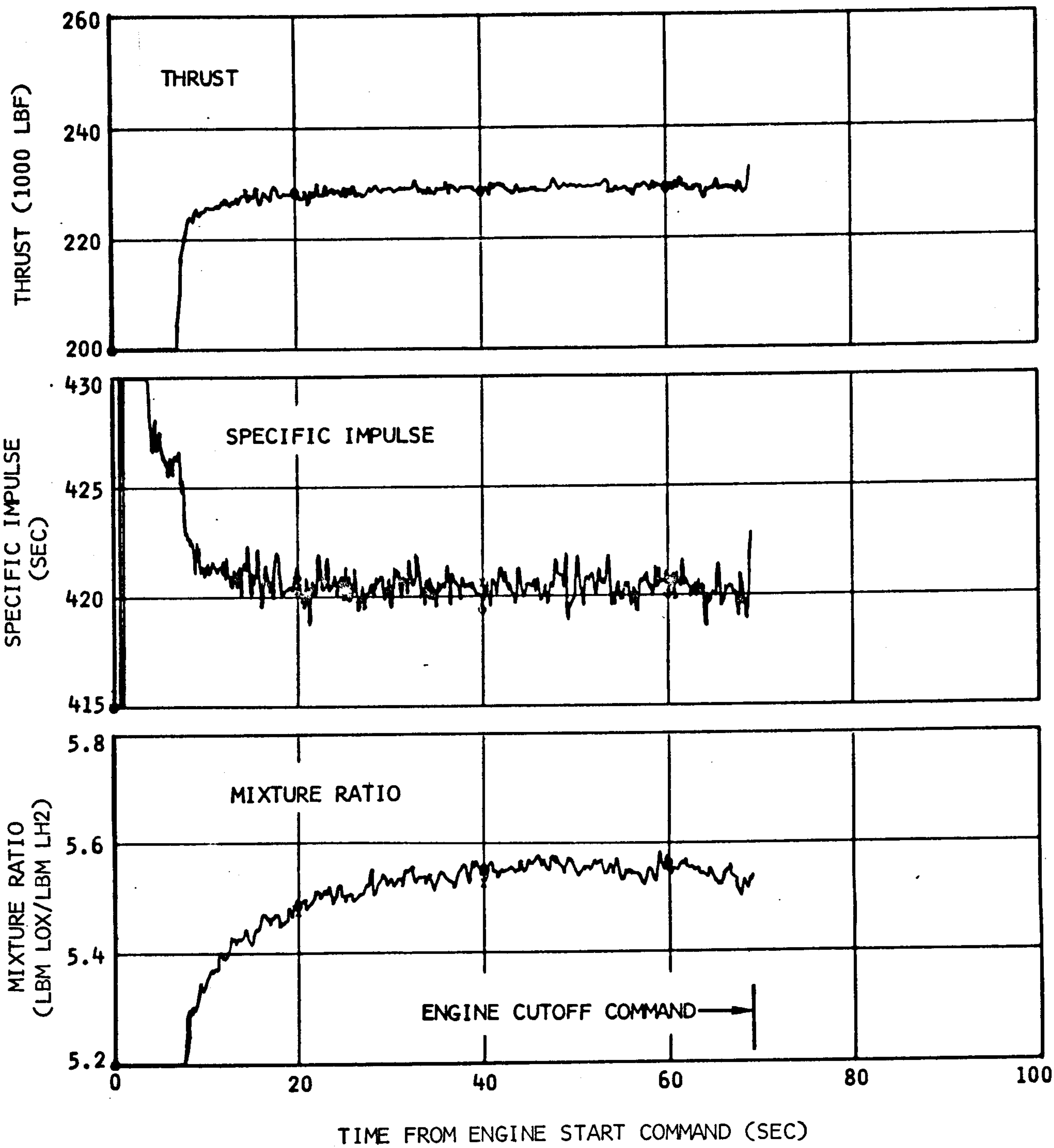


Figure 6-20. Engine Steady-State Performance -- Verification Firing (Sheet 2 of 2)

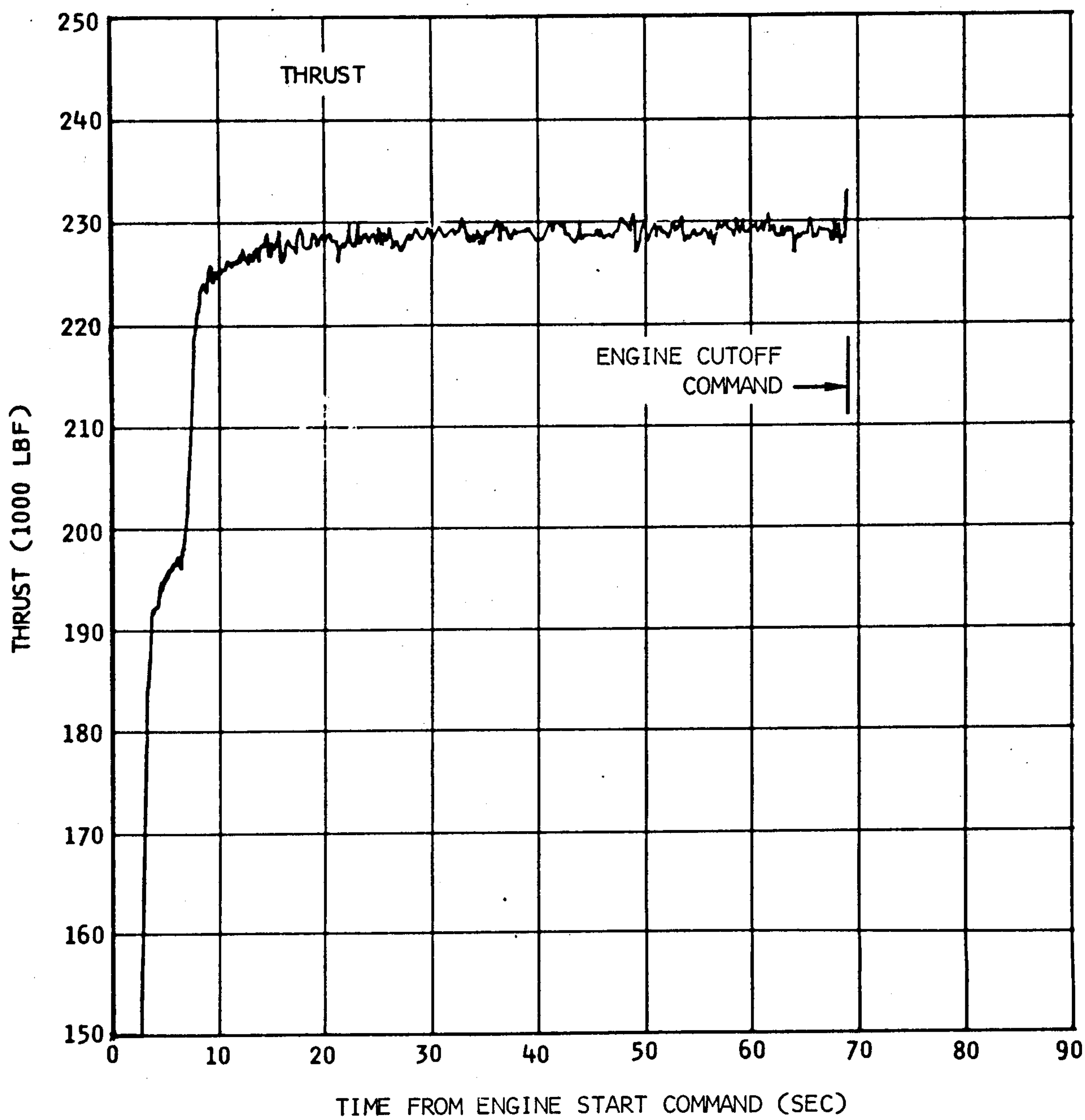


Figure 6-21. J-2 Engine Thrust History -- Verification Firing

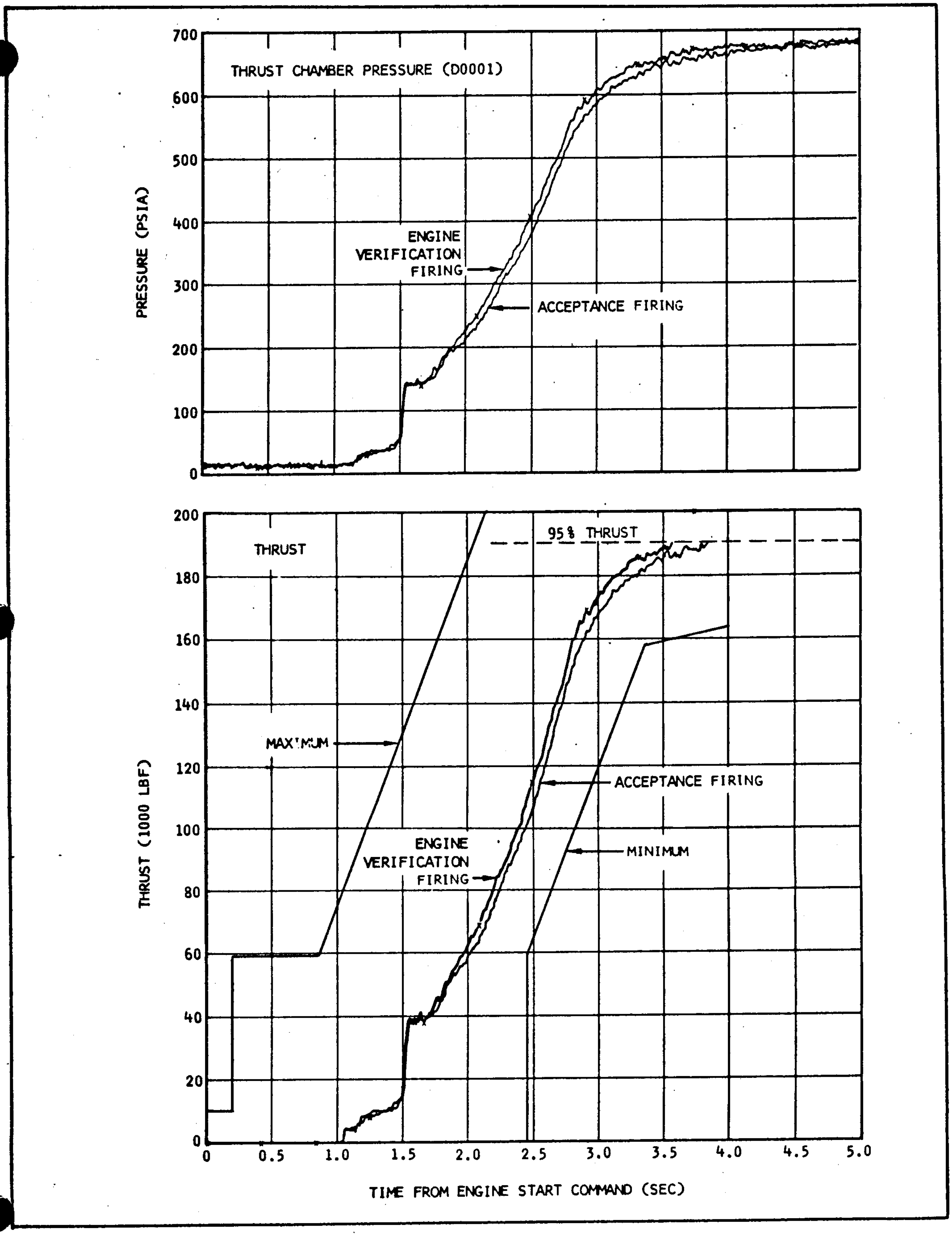


Figure 6-22. Engine Start Transient Characteristics

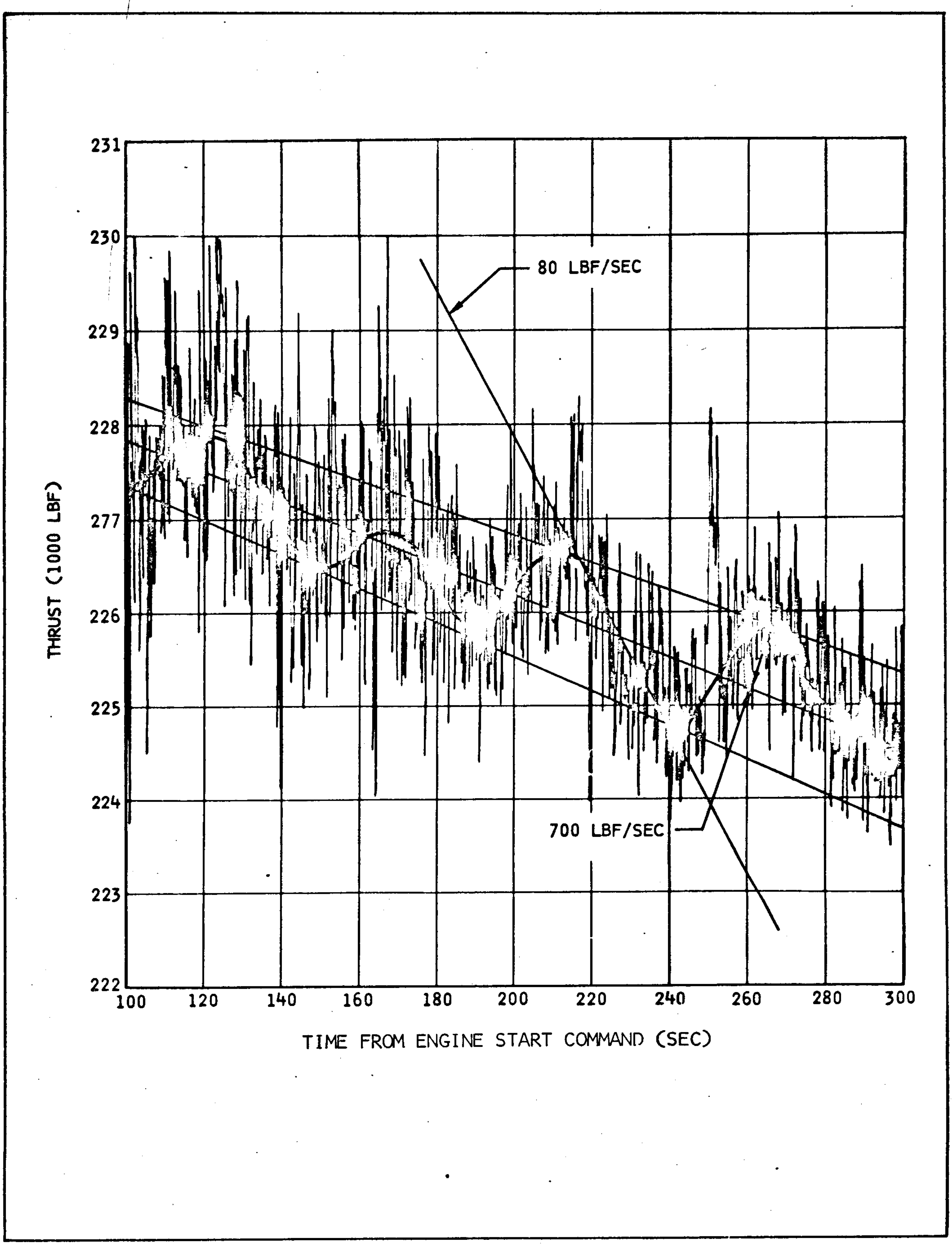


Figure 6-23. Engine Performance Degradation

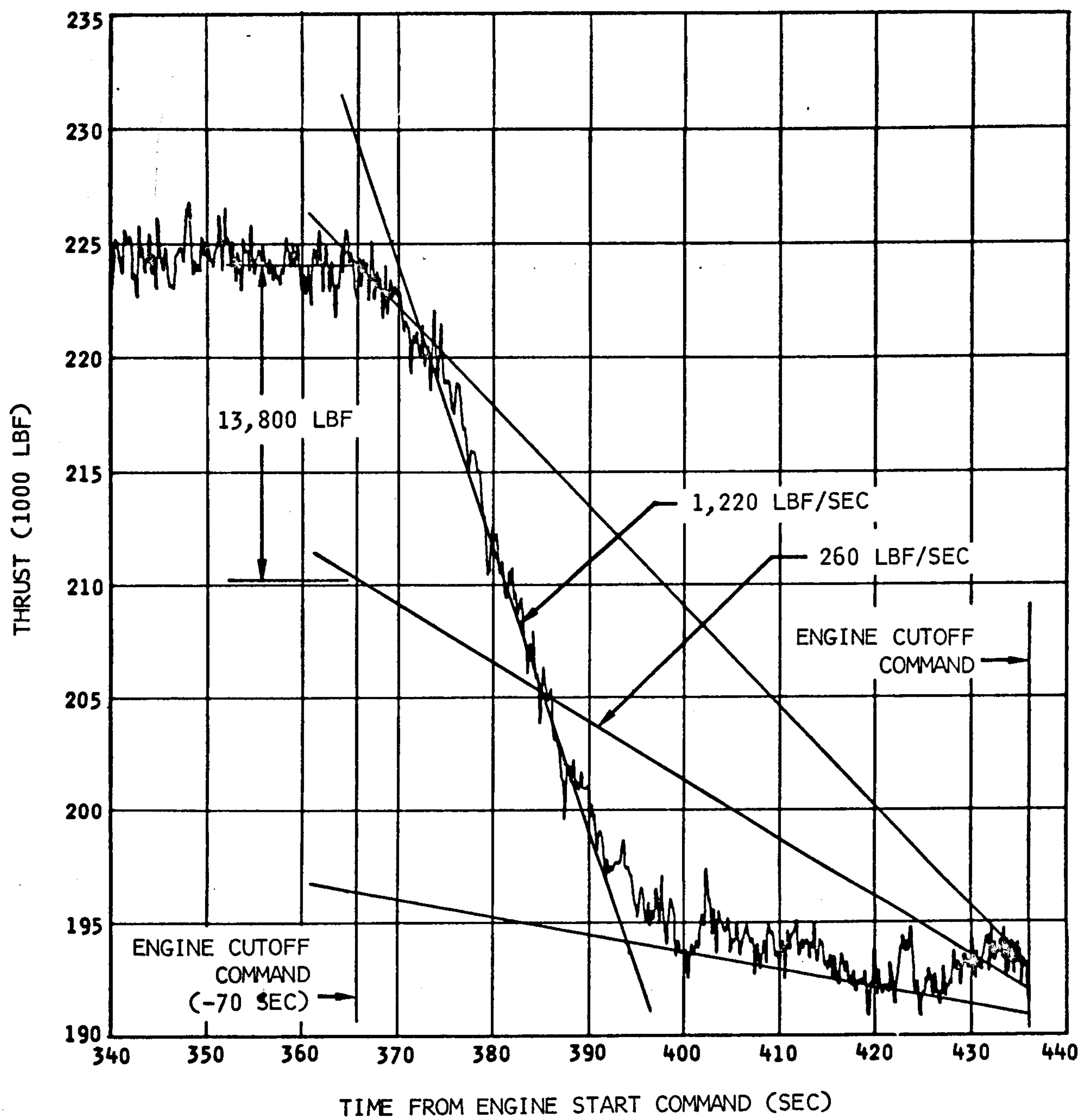


Figure 6-24. Thrust Oscillation -- Definition

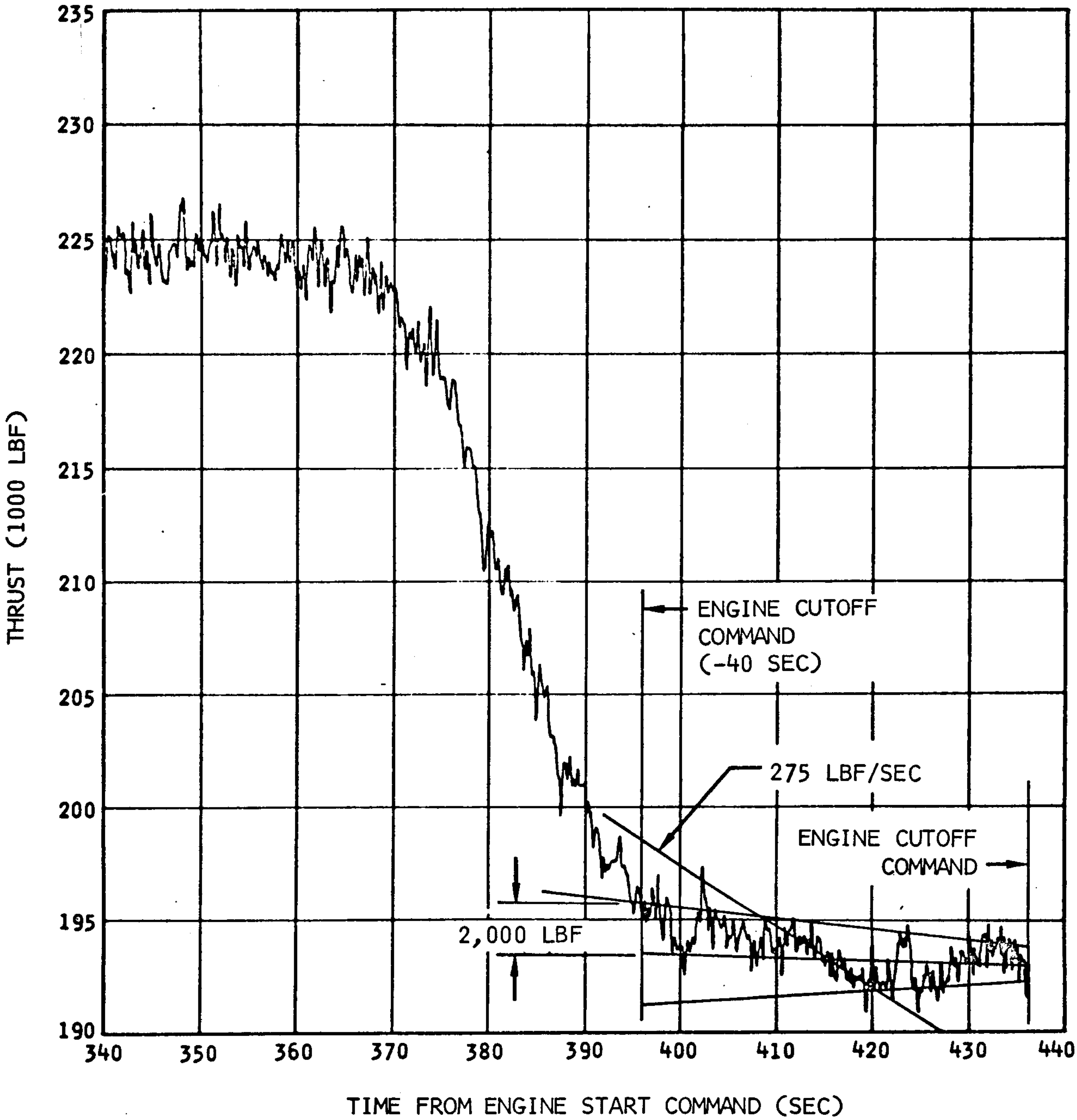


Figure 6-25. Thrust Oscillation -- Actual

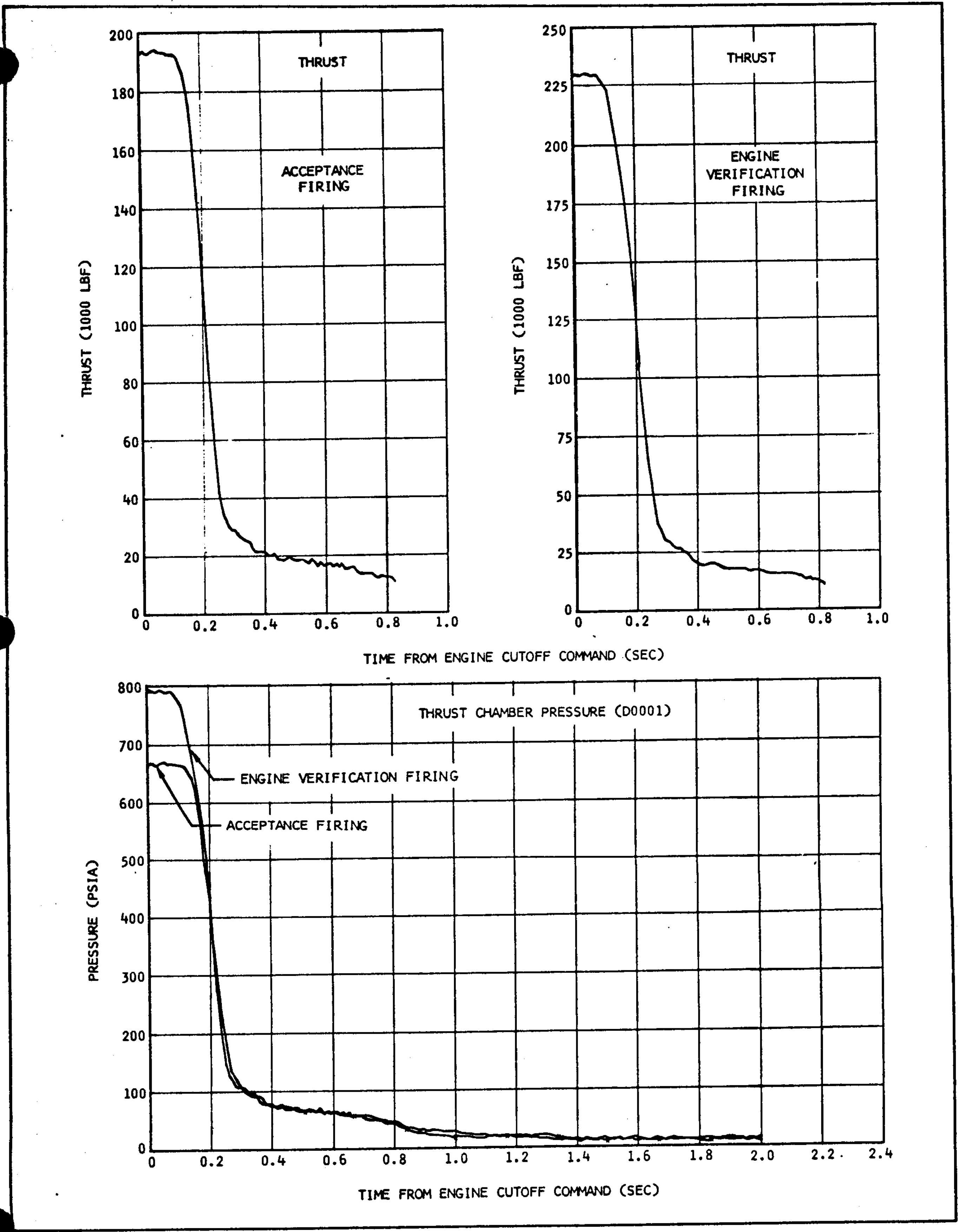


Figure 6-26. Engine Cutoff Transient Characteristics

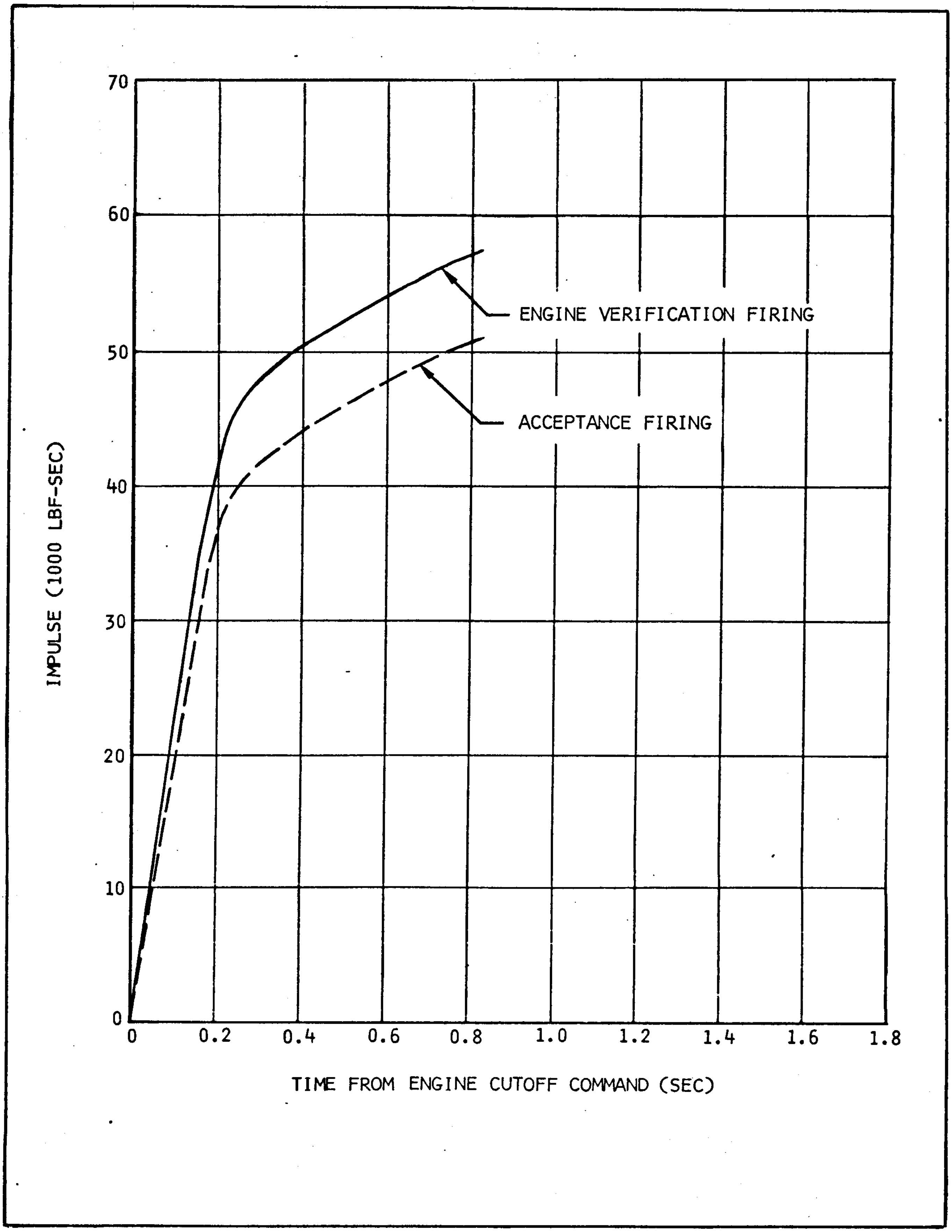


Figure 6-27. Total Accumulated Impulse After Engine Cutoff Command

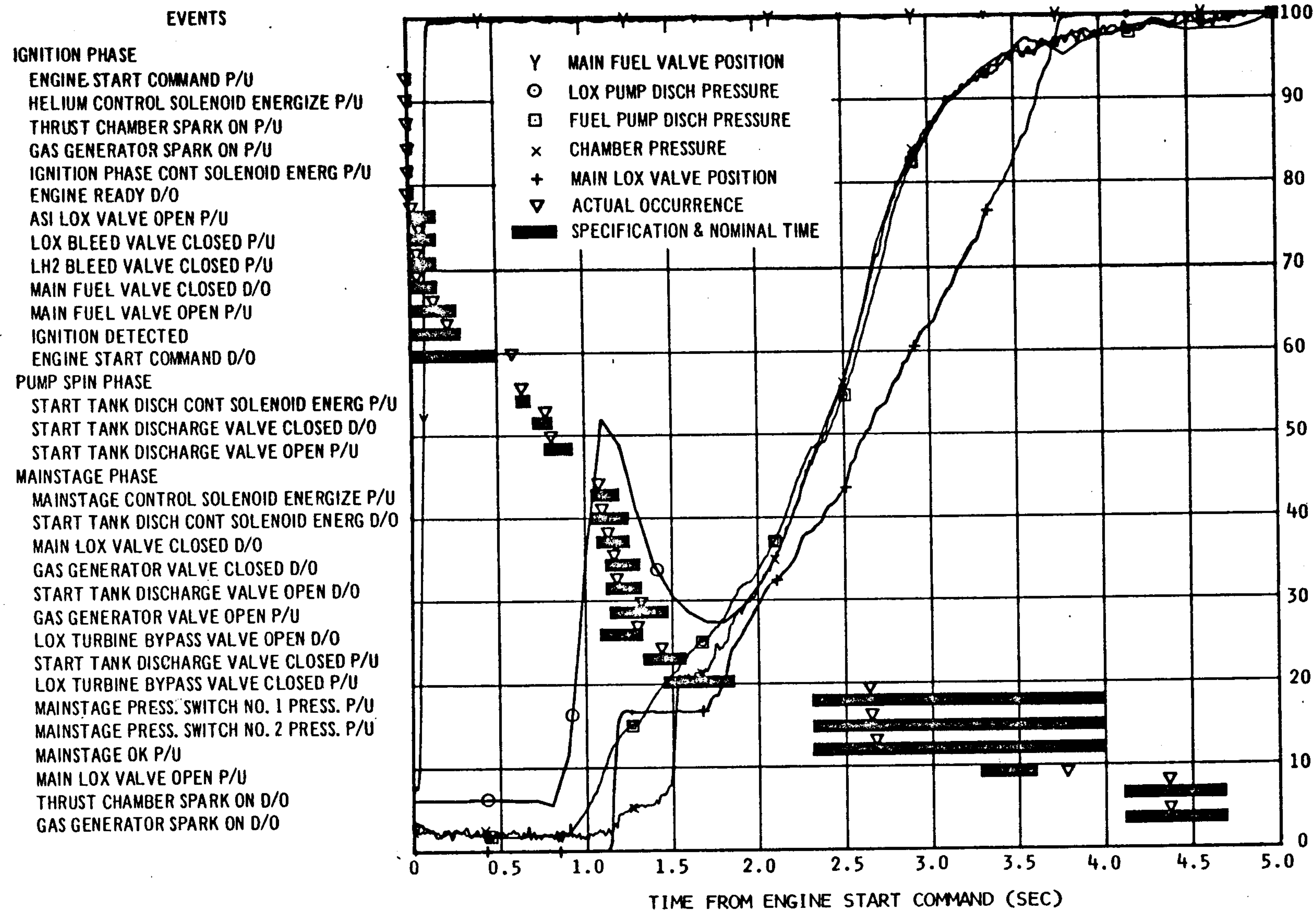


Figure 6-28. Engine Start Sequence

7. OXIDIZER SYSTEM

Throughout the acceptance firing, the oxidizer system functioned adequately, supplying LOX to the engine pump inlet within the specified operating limits. The available net positive suction head (NPSH) at the LOX pump inlet exceeded the engine manufacturer's minimum requirement at all times.

The LOX tank was satisfactorily prepressurized to the upper pressure switch setting; the ullage pressure then decreased to the low pressure switch setting as the pressurant cooled. One makeup cycle was required to maintain the ullage pressure within the required band. Two vent cycles were required to keep the LOX pump inlet pressure less than 52 psia at engine start. The ullage pressure then decreased normally and recovered after the secondary flow was activated; secondary flow was required six times. The ullage pressure, after the usual initial decrease to a minimum, was maintained within an operating pressure band of 36.9 to 38.9 psia.

The cold helium consumption was 148 lbm during the firing.

7.1 Pressurization Control and Internal Environment

The LOX tank pressurization system (figure 7-1) satisfactorily maintained pressure in the LOX tank throughout the acceptance firing. All components of the system performed close to their design requirements.

7.1.1 Prepressurization

LOX tank prepressurization was initiated 312 sec prior to Engine Start Command and increased the LOX tank ullage pressure from ambient to 40.2 psia within 13 sec (figure 7-2). One makeup cycle was required to maintain the LOX tank ullage pressure before the ullage temperature stabilized. After the makeup cycle, the ullage pressure decreased to 39.3 psia; subsequently, the ambient helium purge of the LOX tank vent valve increased the ullage pressure until ESC -210 sec, when the ullage pressure reached 42.4 psia and the vent relief valve opened. The valve relieved the ullage until ESC -120 sec when the vent valve was cycled, and the pressure decreased to 38.6 psia. This was accomplished to maintain the LOX pump inlet pressure below the 52 psia engine start limitation. The pressure again increased and reached the relief setting at ESC -60 sec. The vent valve was again cycled at ESC -40 sec, and the pressure decreased to 38 psia. At engine start the pressure was 38.3 psia.

The pressure increased more rapidly than it did on the S-IVB-205 stage because the larger LOX load caused the ullage volume to be 58 cu ft smaller than the ullage volume of the S-IVB-205 stage; therefore, the effect of the purge on the S-IVB-206 stage ullage pressure was more significant. The prepressurization flowrate varied from 0.25 to 0.33 lbm/sec and was calculated from temperature and pressure data upstream of the prepressurization control orifice. During prepressurization, 5.2 lbm of helium were added to the LOX tank ullage: 3.3 lbm during the main prepressurization and 1.9 lbm during the makeup cycle.

7.1.2 Pressurization

During the engine firing, the LOX tank ullage pressure was satisfactorily maintained by the flight pressurization system. At Engine Start Command the ullage pressure was 38.3 psia. During the start transient, it dropped to a minimum of 32.9 psia before the pressurant flow increased enough to cause the ullage pressure to recover. Secondary flow was required six times during the firing which was two times less than predicted. The pressure control band was 36.9 to 38.9 psia which was approximately 0.5 psi less than the post-test pressure switch check of 37.3 to 39.4 psia (figure 7-3).

The LOX tank pressurization total flowrate varied from 0.38 to 0.44 lbm/sec during overcontrol, and from 0.27 to 0.31 lbm/sec during undercontrol. The variation in total flowrate was caused by a variation in the bypass flowrate. This variation is normal because the bypass orifice inlet temperature changes with time as it follows the cold helium sphere temperature. Predicted total flowrates were 0.34 to 0.40 lbm/sec during overcontrol and 0.23 to 0.26 lbm/sec during undercontrol. Helium consumption as calculated by integrating the total flowrate was 148 lbm.

7.2 Cold Helium Supply

At Engine Start Command, the six cold helium spheres were loaded to 251 lbm of helium at 3,020 psia and 40 deg R. As helium was consumed from the spheres, the temperatures of sphere 5, 2, 3, and 1 decreased as expected (figure 7-4). The temperature of each sphere then increased as the sphere was uncovered. At Engine Cutoff Command, the cold helium spheres contained 91 lbm of helium at 700 psia. The sphere temperatures ranged from 41.2 to 51 deg R. Helium consumption during the firing, based on upper temperature and pressure conditions was 160 lbm. A summation of helium flowrates calculated at the control orifice temperature and pressure conditions indicates a usage of 148 lbm. The agreement between the two helium consumption values is not as good as usual, but it is still within data accuracy. Also, the compressibility factor for helium at low temperatures is not accurately known. Only a small difference in the factor could account for the differences noted.

7.3 J-2 Heat Exchanger

The J-2 heat exchanger functioned satisfactorily. At Engine Start Command the heat exchanger inlet temperature (figure 7-5) decreased gradually and stabilized near 60 deg R during overcontrol and 70 deg R during undercontrol. At engine cutoff it was 80 deg R. The heat exchanger outlet temperature increased to 960 deg R at ESC +80 sec. The temperature then varied between 960 deg R during overcontrol and 990 deg R during undercontrol for the high engine mixture ratio portion of the firing. After the PU ratio valve came off the stop, the outlet temperature began to decrease and reached 930 deg R at engine cutoff. The temperature loss in the 10 ft of uninsulated line between the heat exchanger outlet and the transducer was estimated to be 14 deg R during overcontrol and 38 deg R during undercontrol. The heat exchanger outlet pressure was normal varying between 338 to 368 psia during overcontrol and 395 to 420 psia during under-control. The pressure stabilized at 410 psia after the last overcontrol cycle. The flow through the heat exchanger was 0.187 to 0.205 lbm/sec during overcontrol and 0.072 lbm/sec during undercontrol.

Throughout the firing the LOX vent inlet pressure reflected the overcontrol and undercontrol operations, averaging 68 psia during overcontrol and 48 psia during undercontrol.

A maximum LOX tank vent inlet temperature of 530 deg R occurred during the first overcontrol mode; the redline value of 560 deg R was not exceeded.

Figure 7-5 also shows a comparison of the LOX tank vent inlet temperature and the theoretical gas mixture temperature. The theoretical mixture temperature is the temperature that would be obtained by a complete mixing of the cold bypass gas and the hot gas from the J-2 heat exchanger neglecting wall heat transfer. This comparison presents an indication of the heat transfer to or from the pressurization lines between the mixing point and the LOX vent inlet.

7.4 LOX Pump Chilldown

The LOX pump chilldown system performed adequately. At Engine Start Command the pump inlet conditions of 47.2 psia and 165.3 deg R were sufficient to produce an NPSH of 30.3 psi, which was well above the required value of 16.5 psi.

The prevalve and gas generator bleed valve were open during loading, allowing LOX to enter the system and cool the engine LOX turbopump and the recirculation system before the chilldown pump was started. Recirculation chilldown was started 145 sec before initiation of tank prepressurization and was terminated shortly before engine start. The prevalve open command was received at ESC -4.41 sec. Dropout of the closed signal occurred 0.96 sec later and was followed by the pickup of the prevalve open signal at ESC -1.62 sec, thus resulting in a delay of 2.79 sec between command and pickup of the prevalve open signal. Bubbles, which might have collected under the prevalve during chilldown, were removed by opening the prevalve with the chilldown pump still running. The chilldown shutoff valve was closed immediately before engine start.

The LOX pump inlet pressure and the chilldown system fluid temperatures are presented in figure 7-6.

During the chilldown process the LOX was subcooled throughout the entire recirculation system. The chilldown flowrate and frictional pressure drop were respectively 39.3 gpm and 8.4 psi prior to prepressurization; subsequently, the flowrate increased to 41.2 gpm with a pressure drop of 9.8 psi through the system. The flow coefficient, a measure of the flow resistance, was calculated from the flowrate and pressure drop data. During pressurized chilldown, it was 16.7 $sec^2/in.^2$-ft^3 (figure 7-7). This value is greater than the coefficients obtained for the S-IVB-204 and S-IVB-205 stages

(14.0 $sec^2/in.^2-ft^3$), indicating a higher flow resistance for the childown system.

When the chilldown pump was started, the NPSH at the turbopump inlet increased from 5.7 to 14.5 psi and remained constant for 2.3 min until prepressurization occurred at SLO -160 sec. The NPSH then increased to 41.4 psi and varied directly with the ullage pressure until the prevalve was opened causing the NPSH to drop from 39.7 to 30.3 psi as a result of the decrease in pump inlet pressure.

The heat input rates (figure 7-7) from the tank to the turbopump inlet (section 1), from the pump inlet to the bleed valve (section 2), and from the bleed valve to the tank inlet (section 3) were computed using flowrate and temperature data. These heat input rates decreased rapidly during the first minute of chilldown and then remained relatively constant during the subsequent chilldown process. During steady-state pressurized chilldown, the heat input rates were within the range of those obtained for previous acceptance firings. These rates were as follows:

Section	Rate (Btu/hr)
1	4,000
2	13,500
3	1,000
Total	18,500

7.5 Engine LOX Supply

The LOX supply system (figure 7-8) delivered the necessary quantity of LOX to the engine pump inlet throughout the engine firing and maintained the pressure and temperature conditions within a range that provided a LOX pump NPSH above the minimum requirement of 20.2 psi at high EMR and 14.3 psi after EMR cutback. The minimum available NPSH at engine cutoff was 18.5 psi. During firing, the LOX pump inlet pressure and temperature were very near the values predicted, resulting in an NPSH profile that agreed closely with predicted values. The LOX pump inlet pressure was 47.2 psia at engine start and decreased to 36.5 psia during the first 20 sec of engine operation. It then cycled with ullage pressure while generally decreasing with time as the LOX in the tank was consumed, resulting in a decreasing liquid head.

The LOX temperature at the pump inlet was 164.7 deg R after the start transient and increased with bulk heating to a maximum of 168.0 deg R at engine cutoff (figure 7-9). The available NPSH at the LOX pump inlet was approximately 30.3 psi at engine start decreasing to 22.3 psi during the first 20 sec of engine firing because of decreasing ullage pressure. The NPSH then cycled with the ullage pressure while generally decreasing with time because of the decreasing liquid head and increasing bulk temperature. By engine cutoff, the NPSH had decreased to a minimum value of 18.5 psi which was well above the allowable minimum of 14.3 psi. The average frictional pressure drop in the LOX suction duct at high EMR was calculated to be 2.6 psi at a flowrate of approximately 450 lbm/sec. After EMR cutback the pressure drop was 1.7 psi at a flowrate of approximately 380 lbm/sec. These pressure drops were within the range of values calculated from previous acceptance firings.

The LOX pump inlet pressure and temperature were plotted in the engine LOX pump operating region (figure 7-10) and showed that the engine LOX pump inlet conditions were met satisfactorily throughout engine firing.

The pump inlet temperature was plotted against the mass remaining in the LOX tank during engine operation. The resulting curve agreed closely with the results of the S-IVB-204 and S-IVB-205 acceptance firings (figure 7-11).

NOTE:
SEE FIGURE 3-1
FOR LEGEND

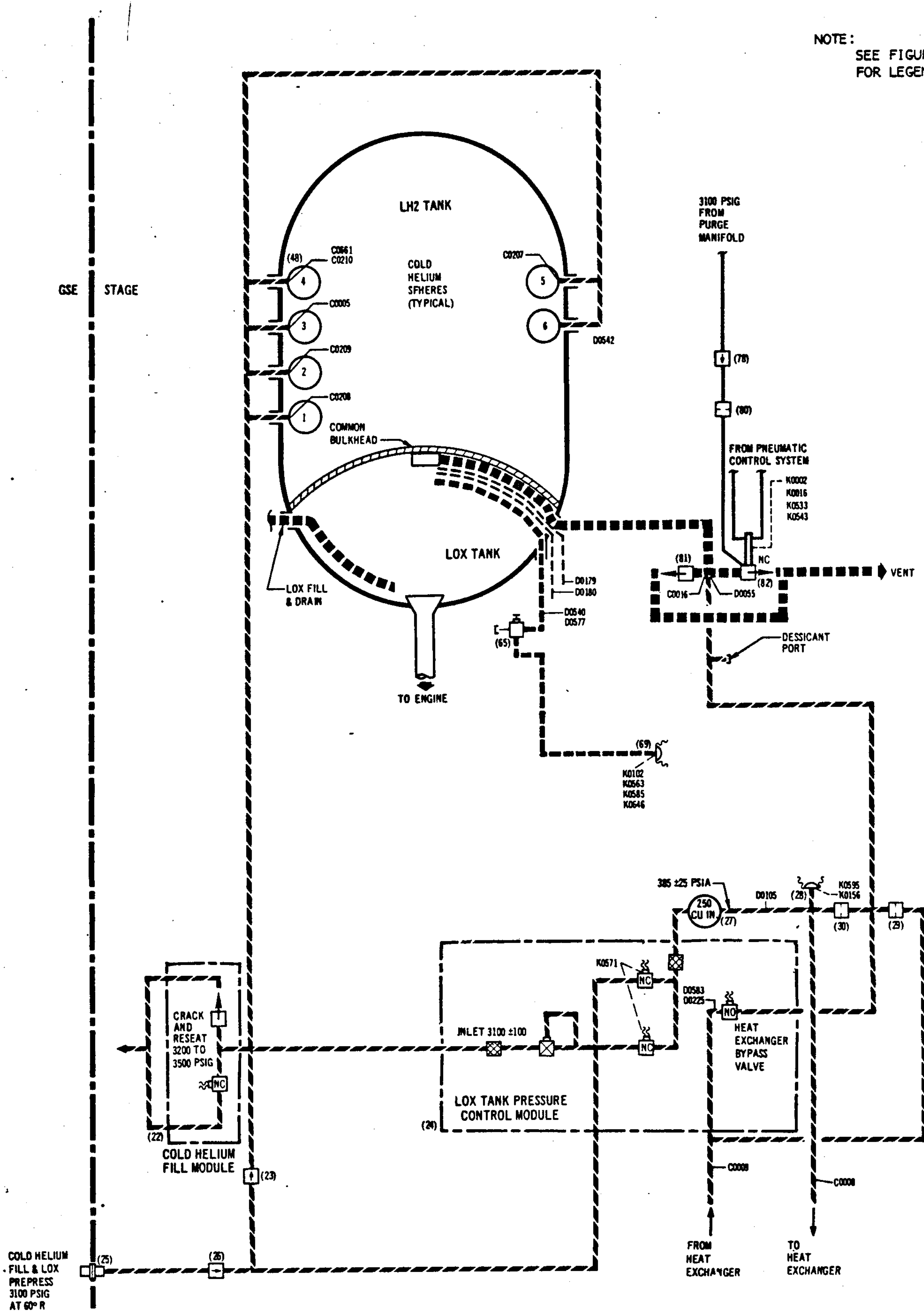


Figure 7-1. LOX Tank Pressurization System

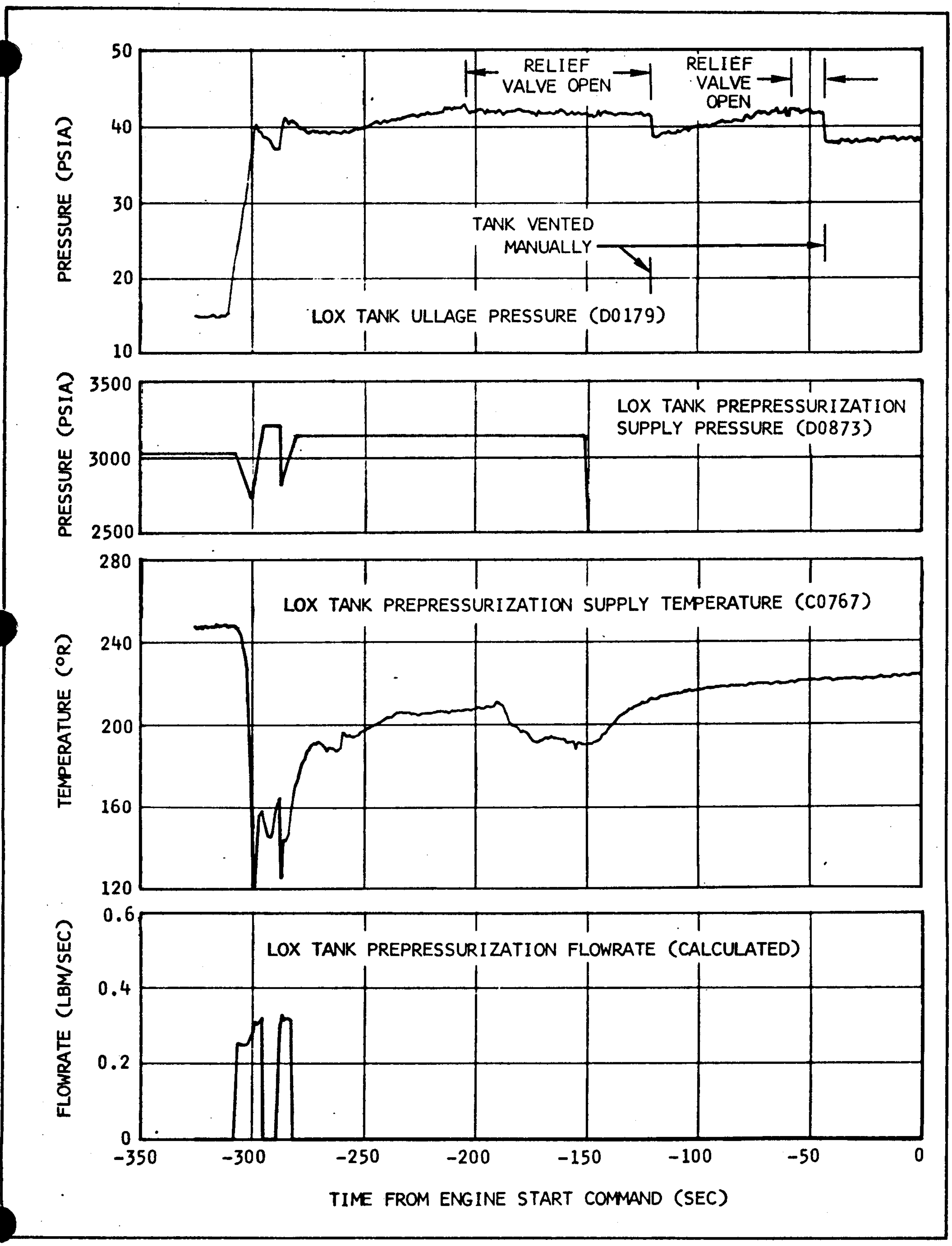


Figure 7-2. LOX Tank Conditions During Prepressurization and Simulated Boost

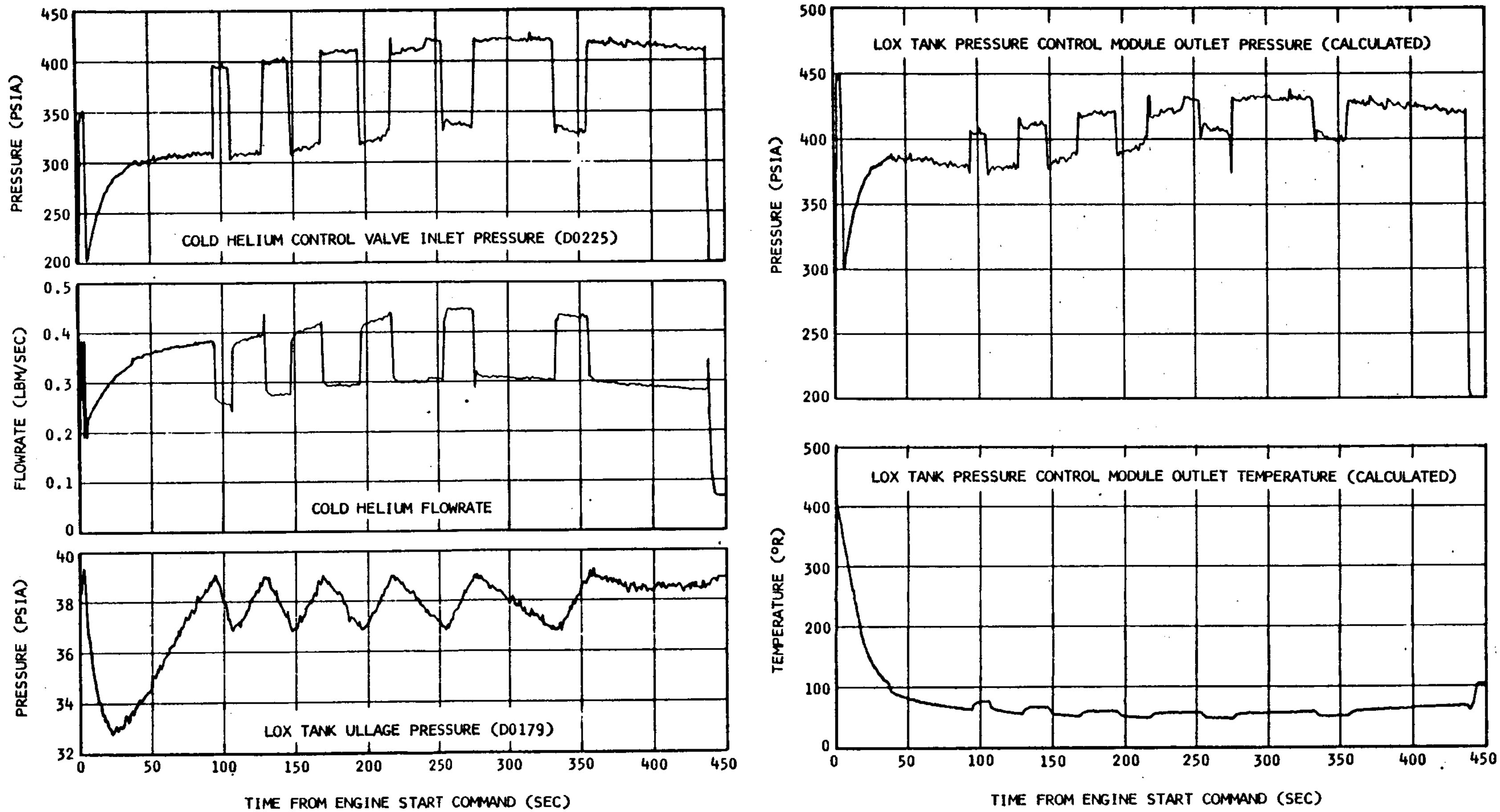


Figure 7-3. LOX Tank Pressurization System Performance

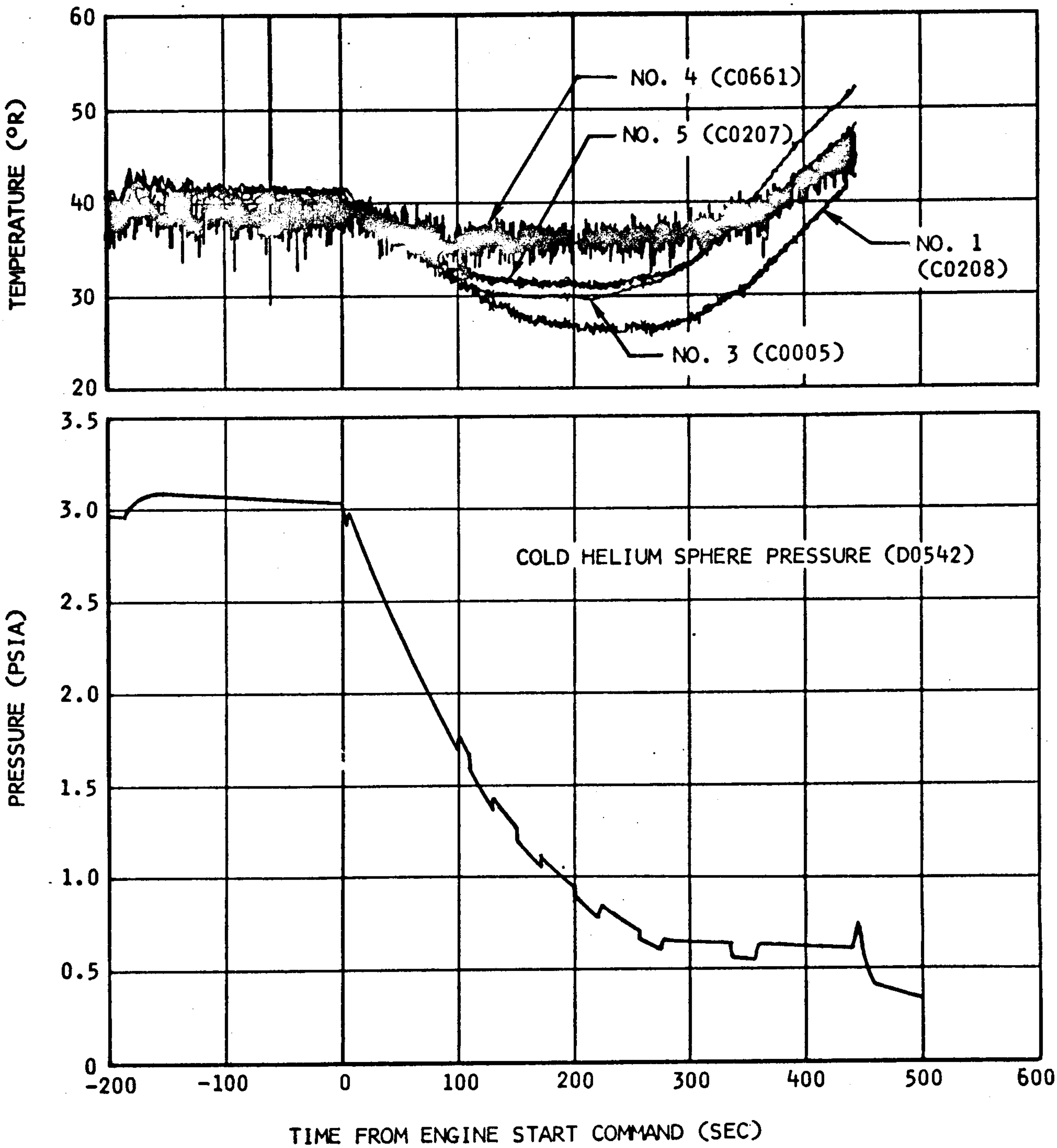


Figure 7-4. Cold Helium Supply

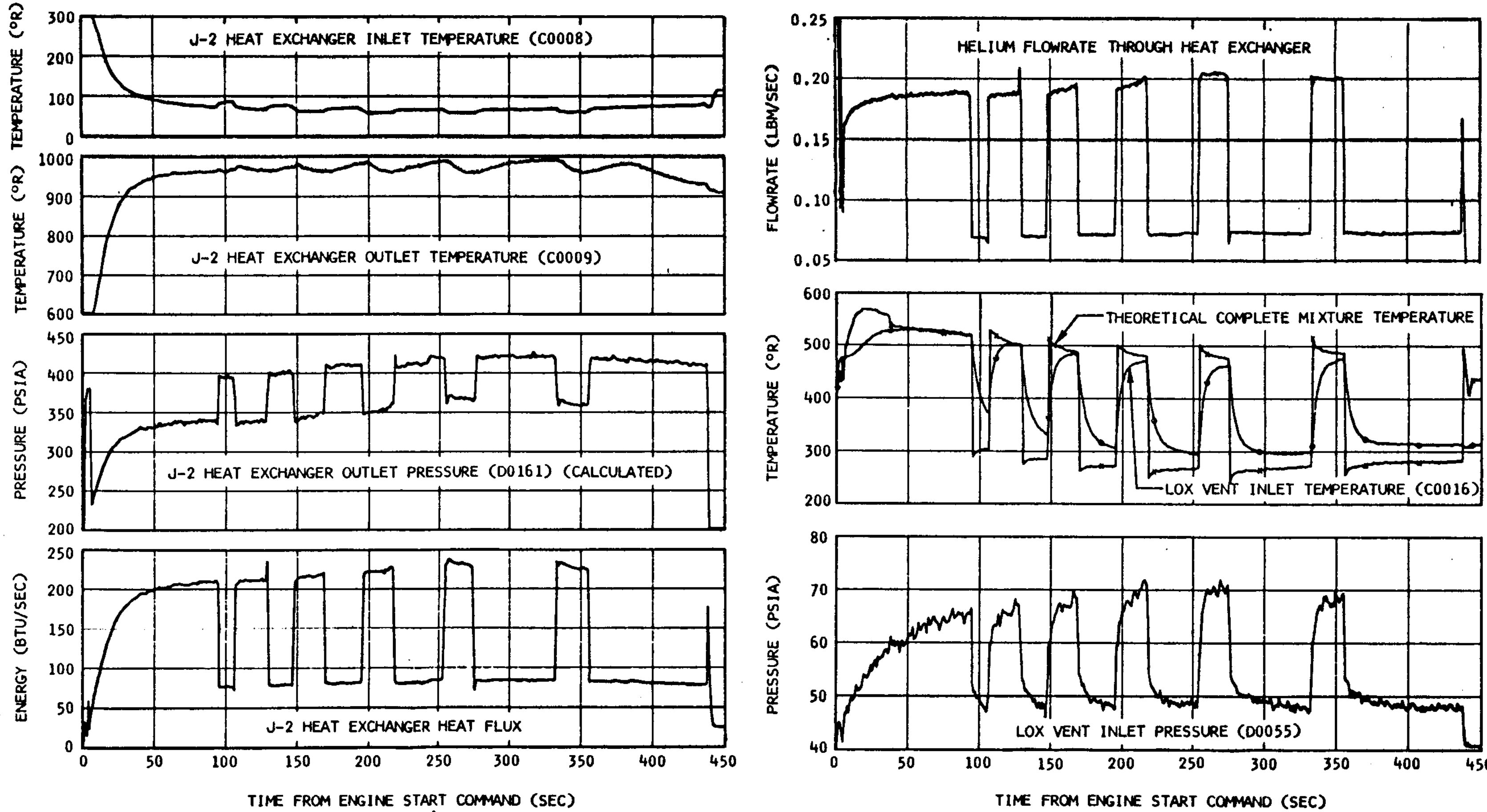


Figure 7-5. J-2 Heat Exchanger Performance

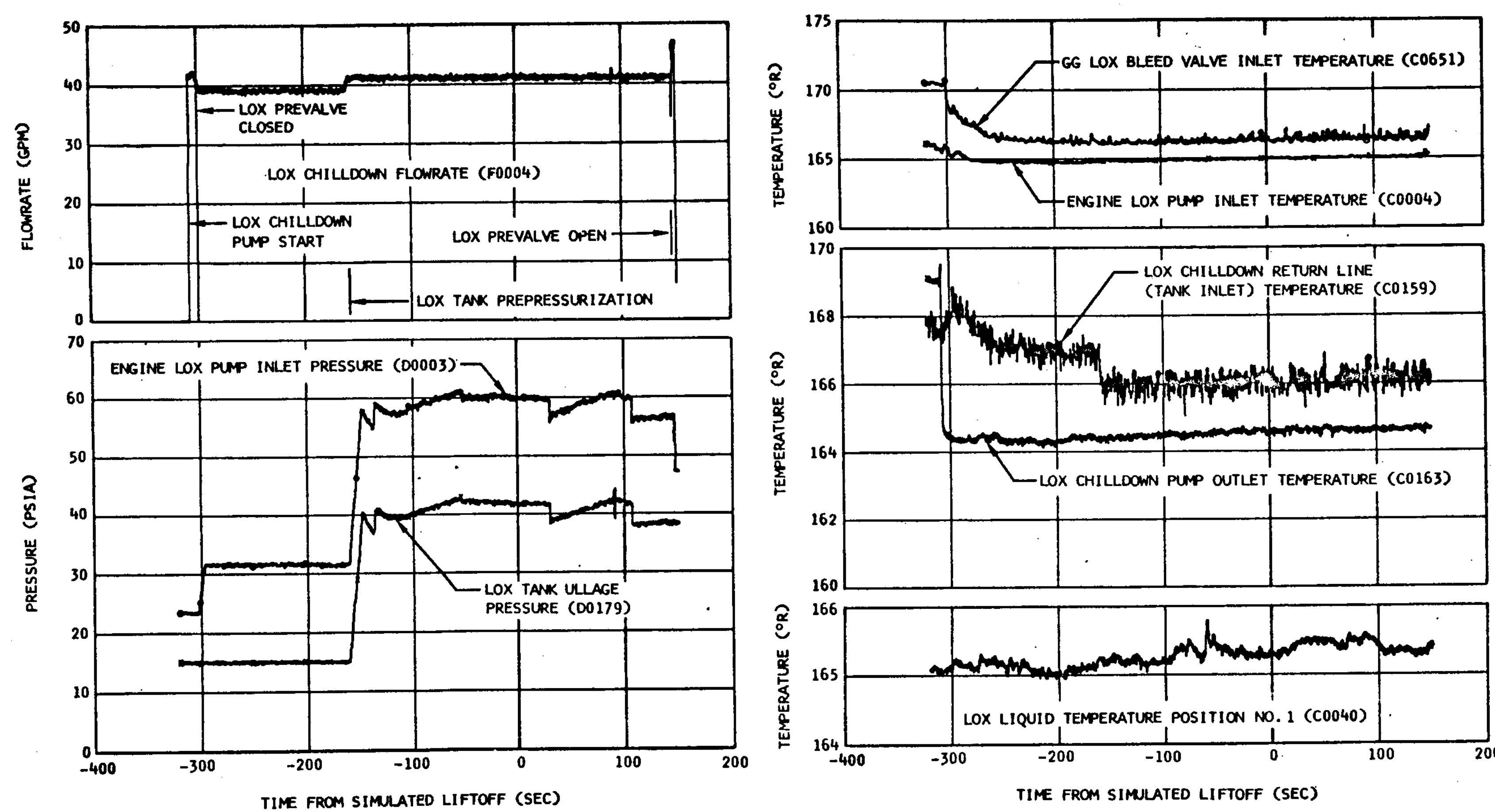


Figure 7-6. LOX Pump Childown System Operation

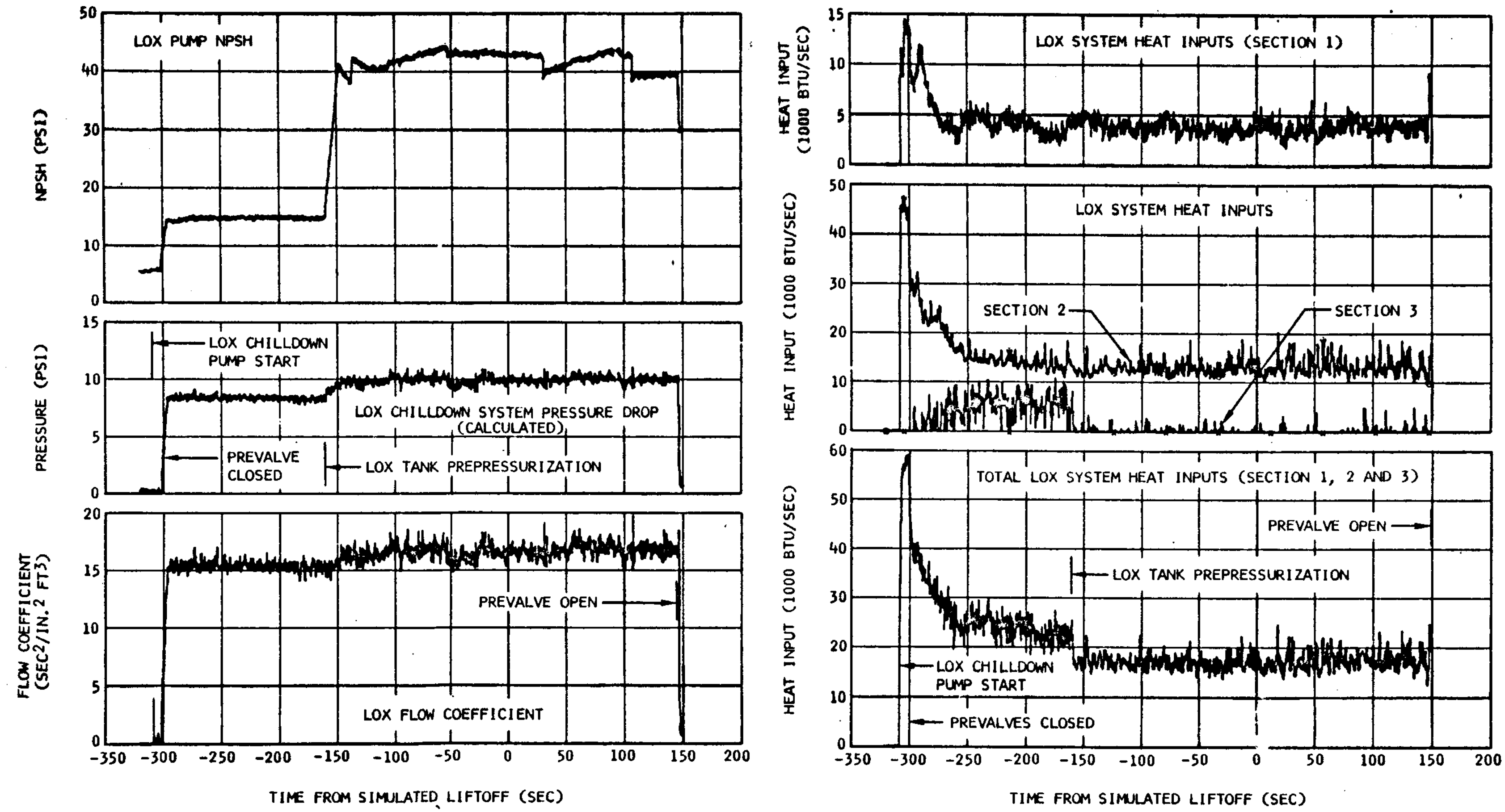


Figure 7-7. LOX Pump Chilldown System Performance

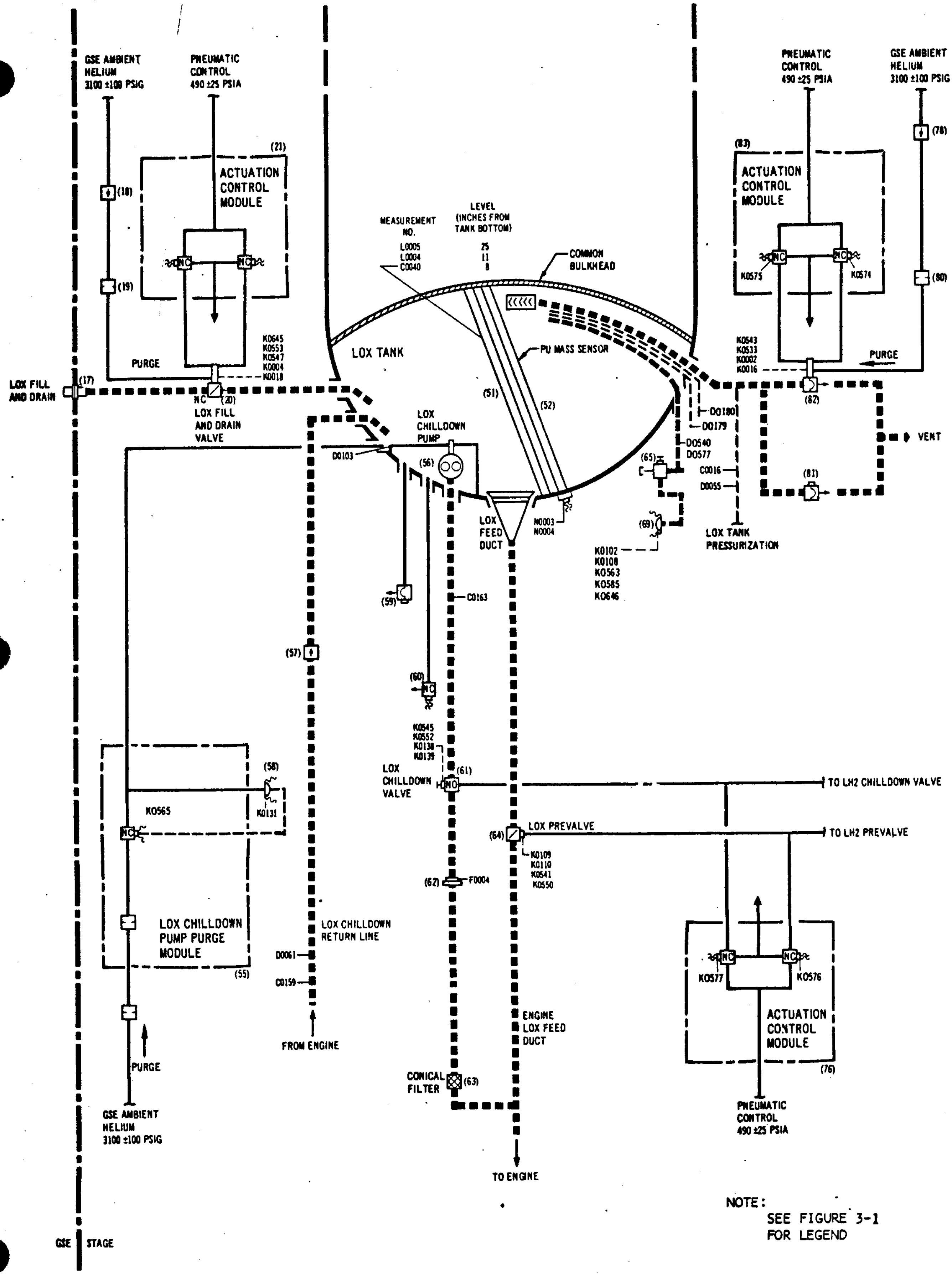


Figure 7-8. LOX Supply System

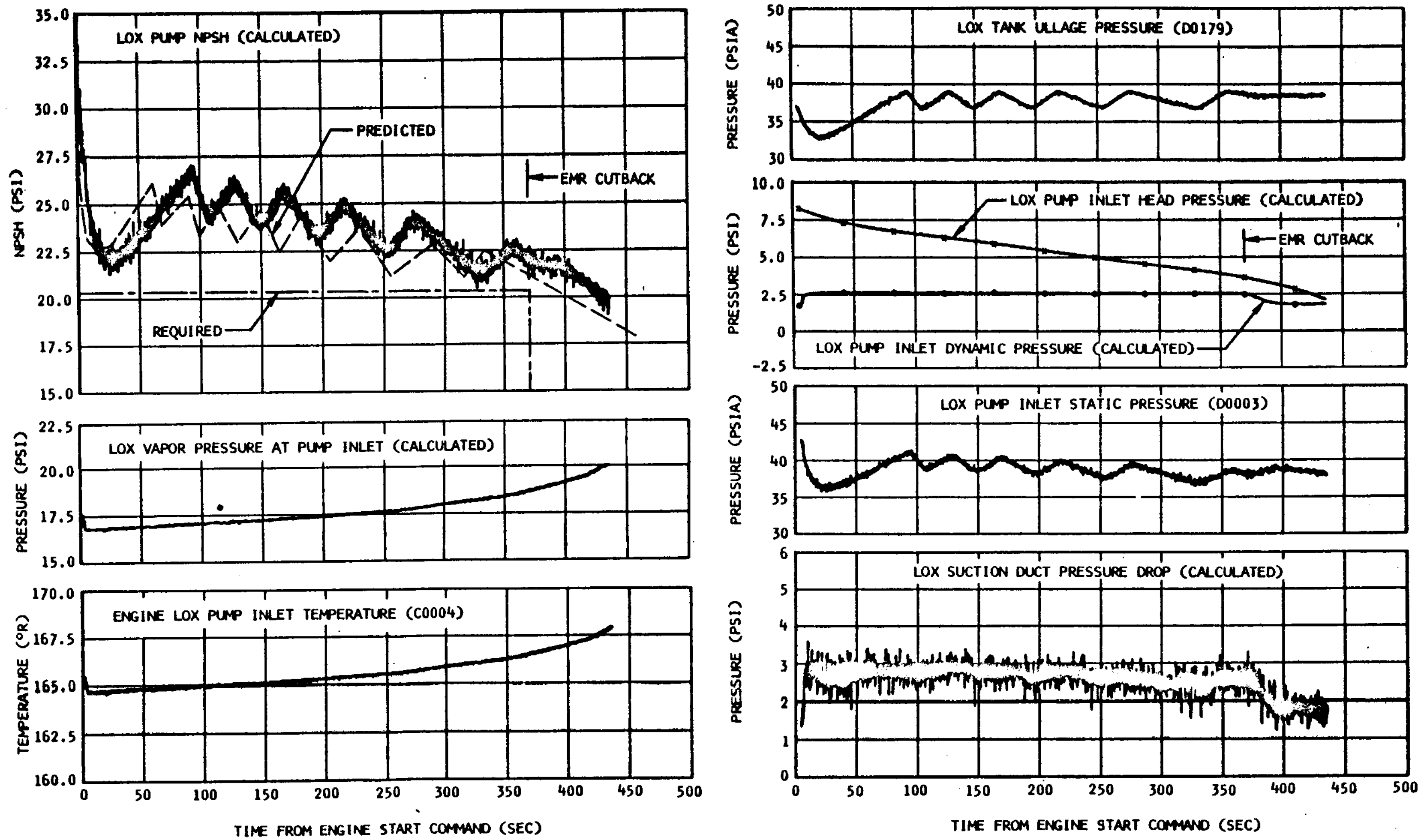


Figure 7-9. LOX Pump Inlet Conditions

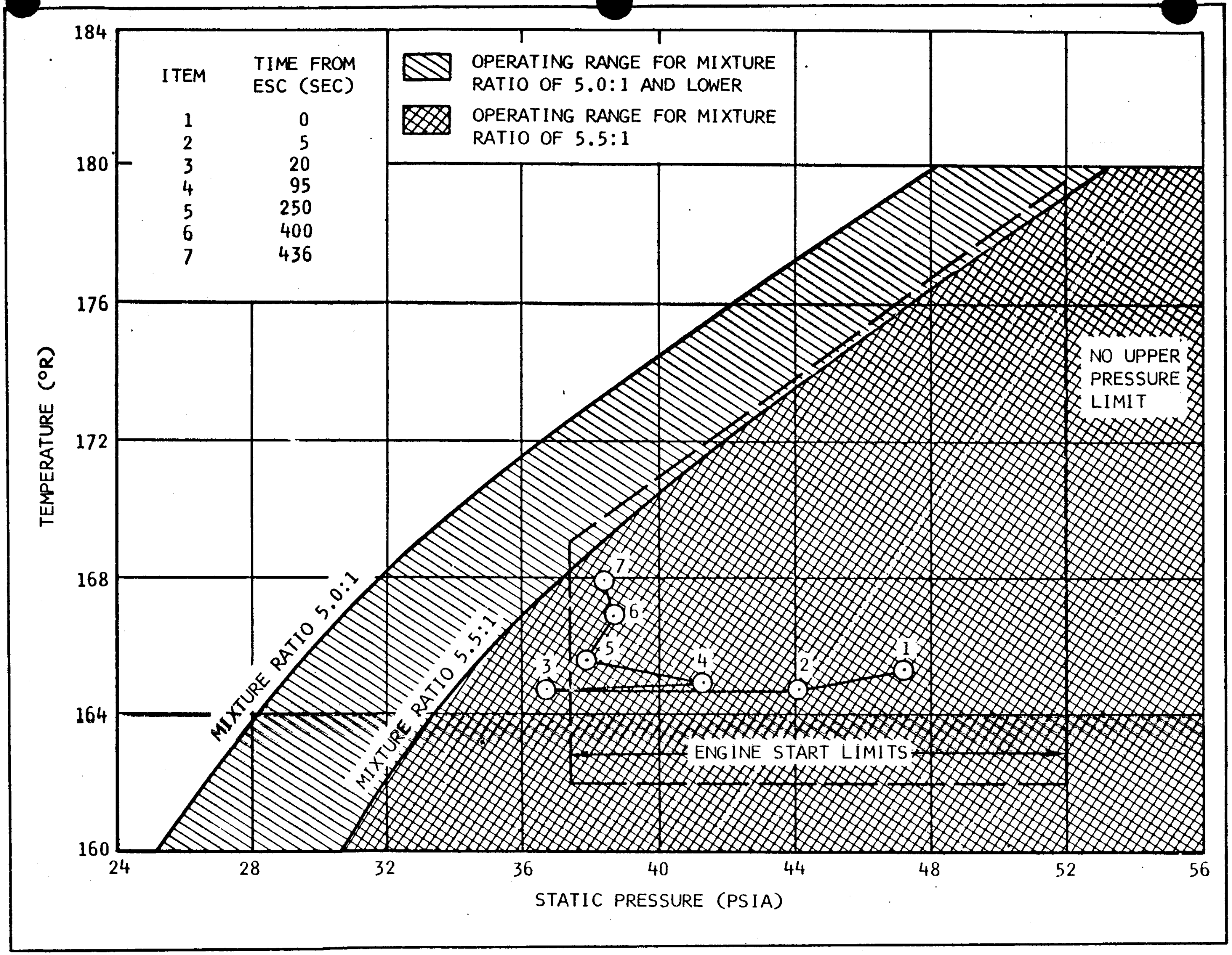


Figure 7-10. LOX Pump Inlet Conditions During Firing

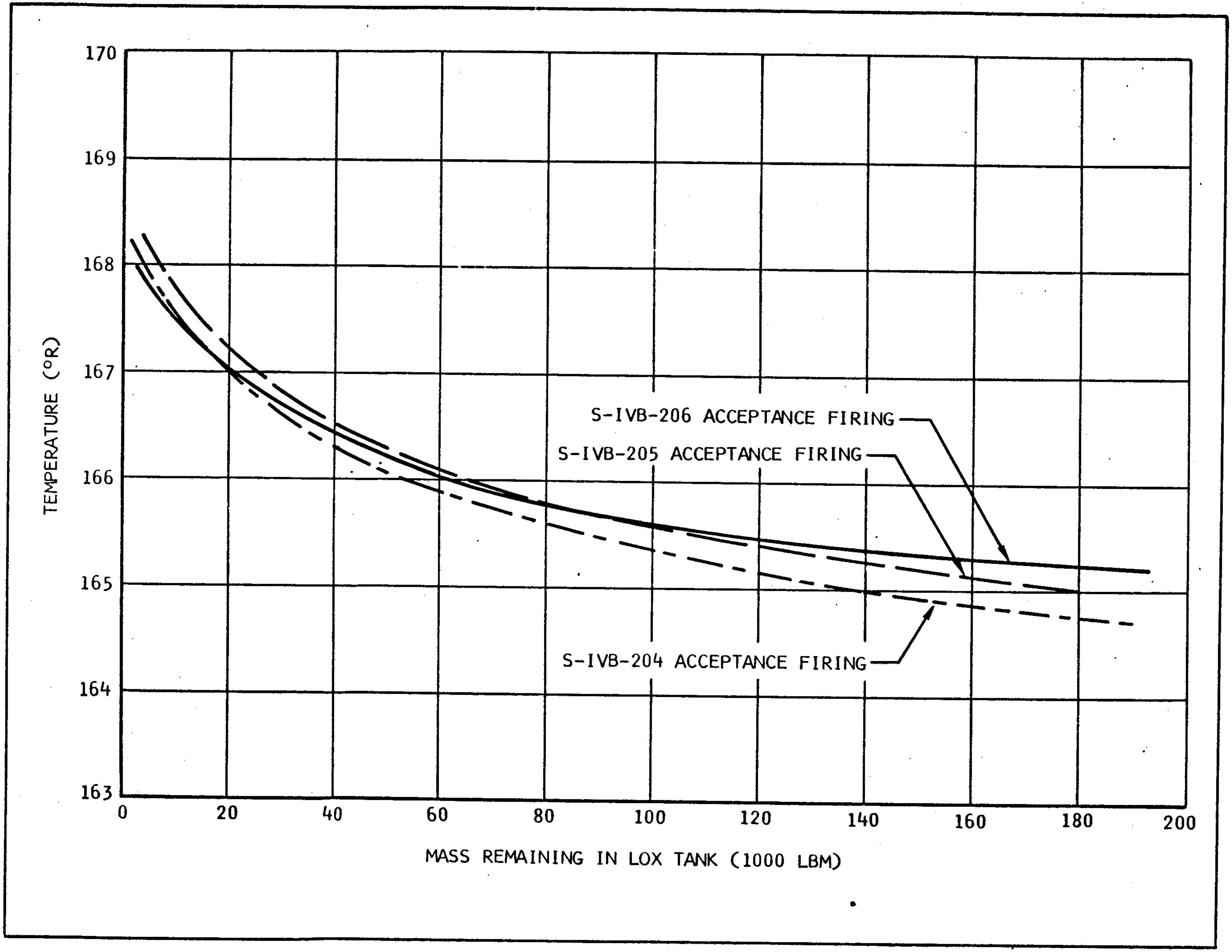


Figure 7-11. Effect of LOX Mass Level on LOX Pump Inlet Temperature

8. FUEL SYSTEM

The fuel system performed as designed and supplied LH2 to the engines within the limits defined in the engine specification. A detailed evaluation of the data, not possible during the acceptance firing, revealed that the observer cutoff due to loss of pump NPSH was not necessary.

8.1 Pressurization Control

8.1.1 Prepressurization

LH2 tank prepressurization was nominal; the pressurization system is shown in figure 8-1 and prepressurization data are presented in table 8-1 and figure 8-2. Because the supply temperature data were not available, an assumed mean temperature based on previous static test experience was used in the helium mass and flowrate calculations.

8.1.2 Pressurization

LH2 tank pressurization was accomplished satisfactorily with no unusual conditions or results. Two complete overcontrol cycles were accomplished before step pressurization because a slightly higher than predicted LH2 flowrate to the engine and a slightly lower than average undercontrol pressurant flowrate contributed to a more rapid ullage pressure decay. This was compounded by the lower than usual ullage pressure at Engine Start Command which caused the first overcontrol cycle to occur earlier than previously, with a resultant shorter duration. Step pressurization began at ESC +301.1 sec, almost coincident with the termination of the second overcontrol cycle, and the resultant high ullage pressure levels caused the tank relief valve to crack open at ESC +407 sec (38.4 psia) and continue relieving for the duration of the firing.

All measured parameters, as shown in table 8-2 and figure 8-3, were within the normal dispersion range. The pressurant collapse factor, at a maximum of 0.85, was again at a low level as a result of the nylon bag inlet diffuser.

8.2 LH2 Pump Childown

The LH2 pump chilldown system performed adequately. At engine start, the pump inlet pressure of 38.5 psia and temperature of 38.6 deg R were within the start requirements. The available NPSH was 18.0 psi, well above the required minimum of 6.4 psi.

System temperatures and pressures and the LH2 chilldown pump flowrate (figure 8-4) were used to determine fluid and hardware temperature conditions, pressure drops, and heat inputs (figure 8-5). The LH2 tank was loaded with the prevalve and gas generator bleed valve open, which allowed a partial hardware chilldown before the chilldown pump was started. Recirculation chilldown was started 195 sec prior to tank prepressurization and terminated shortly before engine start. To remove any bubbles which might have collected under it during chilldown, the prevalve was commanded open at ESC -4.412 sec, while the pump was still running. The chilldown shutoff valve was commanded closed just prior to engine start.

The chilldown pump flowrate (figure 8-4) went through a normal start transient, reaching a value of 108 gpm at the end of the transient. At the initiation of prepressurization (SLO -110 sec), the flowrate increased to and stabilized at 143 gpm until the termination of chilldown at SLO +147 sec.

During the initial portion of the unpressurized chilldown, the heat input rate into section 1 (tank to engine) was close to that required to raise the LH2 temperature to saturation (21,000 Btu/hr calculated input as compared with 25,900 Btu/hr required to saturate the liquid). As the unpressurized portion of the chilldown progressed, the slight increase in flowrate and a slight decrease in heat absorbtion rate combined to produce approximately 3.4 deg R of subcooling at the pump inlet.

The heat input rates to the chilldown system during S-IVB-501, 205, and 206 stage testing are shown in the following table:

Unpressurized (Btu/hr)				Pressurized (Btu/hr)			
Section	S-IVB-501	S-IVB-205	S-IVB-206	Section	S-IVB-501	S-IVB-205	S-IVB-206
1	18,000	25,000	21,000	1	13,000	21,000	17,500
2 and 3	30,000	25,000	18,000	2	27,500	13,000	22,000
				3	13,500	32,000	21,500
Total	48,000	50,000	39,000	Total	54,000	66,000	61,000

Only a very general comparison of the heat inputs, particularly those of the individual sections, can be made because of the large effects of minor temperature inaccuracies.

Immediately after prepressurization, the LH2 pump inlet temperature decreased as the flowrate increased. After reaching a minimum of 38.2 deg R, the temperature slowly increased as the LH2 bulk warmed until, at engine start, the temperature was 38.6 deg R. After prepressurization all of the heat inputs went into heating the pressurized fluid, and no vaporization occurred because all temperatures were less than saturation. After prepressurization was terminated at SLO -42 sec, the pump inlet pressure followed the ullage pressure until the prevalve was opened. At that time essentially all of the flow returned to the LH2 tank through the prevalve with no flow through the chilldown system. The pump inlet pressure then decreased because of loss of chilldown pump head to 38.5 psia where it remained until engine start. The LH2 prevalve sequencing was as follows:

Event	Time
Valve open command	ESC -4.412 sec
Left closed position	ESC -3.536 sec
Reached open position	ESC -1.619 sec

The NPSH at the LH2 pump inlet followed the ullage pressure during prepressurization and reached a maximum of 25.5 psia by the time the prevalve was opened. It then decreased to 18.0 psi because of the loss of chilldown pump head.

The flow coefficient, calculated from flowrate and chilldown system pressure drop data, averaged 18.2 $sec^2/in.^2ft^3$ (figure 8-5). This value agreed with those calculated for previous S-IVB stages. The coefficient was used to compute average fluid quality during the unpressurized phase of the chilldown.

The average fluid quality in sections 2 and 3 where two-phase flow existed during unpressurized chilldown was 0.025 lbm gas/lbm two-phase mixture.

The quality decreased to zero during prepressurization when the fluid in the system became subcooled. The LH2 chilldown system pressure drop was relatively steady at 9.0 psi during the unpressurized chilldown.

8.3 Engine LH2 Supply

The engine LH2 supply system (figure 8-6) provided LH2 to the engine within specifications throughout the firing; however, the LH2 pump inlet temperature transducer (C0658) was reading approximately 1.6 deg R high, causing the firing to be manually terminated because of low NPSH, although the actual NPSH, which was well above the minimum limit of 5.6 psi, was later calculated to be 10.2 psi.

The LH2 pump inlet static pressure was 38.5 psia at engine start. It then followed the ullage pressure, reaching a minimum of 26.0 psia at ESC +125 sec. After step pressurization was initiated, the pressure increased to 37.5 psia at engine cutoff. After the start transient, the LH2 temperature at the pump inlet was 37.3 deg R and increased with bulk heating to a maximum of 38.6 deg R shortly before engine cutoff (figure 8-7).

The available NPSH at the LH2 pump inlet at engine start was approximately 18.0 psi. It increased to a maximum of 21.5 psi immediately after engine start as the LH2 in the suction duct was replaced by the colder LH2 from the tank, resulting in a lower saturation pressure at the pump inlet. The NPSH then followed the ullage pressure, decreasing to a minimum of 9.5 psi at ESC +245 sec, which was 3.7 psi above the minimum required at that time. It then increased until the initiation of step pressurization when it began increasing at a more rapid rate until approximately ESC +400 sec, because the increasing ullage pressure had a larger effect on the NPSH than the decreasing liquid head and increasing LH2 temperature. From this time until engine cutoff, the NPSH decreased slightly because the tank ullage was being maintained at a constant level by relief valve action, and the LH2 vapor pressure increase that resulted from the increasing pump inlet temperature was the driving factor. The actual NPSH profile agreed closely with the maximum NPSH prediction.

The average frictional pressure drop in the LH2 suction duct was calculated to be 0.5 psi at a flowrate of 81 lbm/min. The data indicate that the pressure drop remained essentially constant following the EMR cutback; however, the small expected change of approximately 0.2 psi could have easily been obscured by the noise level that is apparent on the data. The pressure drop noted was lower than the range of values (0.9 to 1.5 psi) noted during previous acceptance firings, but was not unreasonable in view of data and computational accuracy.

The LH2 pump inlet pressure and temperature were plotted in the engine operating region (figure 8-8) and showed that the engine LH2 pump inlet conditions were met satisfactorily throughout engine firing. Figure 8-9 is a plot of the pump inlet temperature versus the mass remaining in the LH2 tank during burn and includes previous acceptance firing data for comparison. The S-IVB-206 acceptance firing data agreed closely with the S-IVB-204 and 205 acceptance firing data.

8.4 Special LH2 Chilldown Shutoff Valve Test

Because the LH2 chilldown shutoff valve failed during S-IVB-202 and S-IVB-203 stage flights, a special test was run during the engine performance verification firing (CD 614072). During this special test, the program was changed such that the chilldown shutoff valve was not commanded to close. The comparative flowrate through the chilldown system during the high EMR engine operations were as follows:

Test	Flowrate (gpm)
S-IVB-202 flight (partially open)	75
S-IVB-203 flight (partially open)	76
S-IVB-206 engine verification (commanded open)	81.5

The level noted on the S-IVB-206 test was slightly higher than that on the flights, during which it was supposed that the actuator which positions the valve was restrained by solidified nitrogen. Since the actuator on the flights was supposedly able to move a short distance, and in fact the valve open signal microswitch was de-activated, the slightly lower flowrate than that seen during the S-IVB-206 test tends to confirm the proposed failure mode. The chilldown pump outlet temperature profile was also similar on all three tests, giving additional confirmation.

8.5 LH2 Tank Internal Insulation Performance

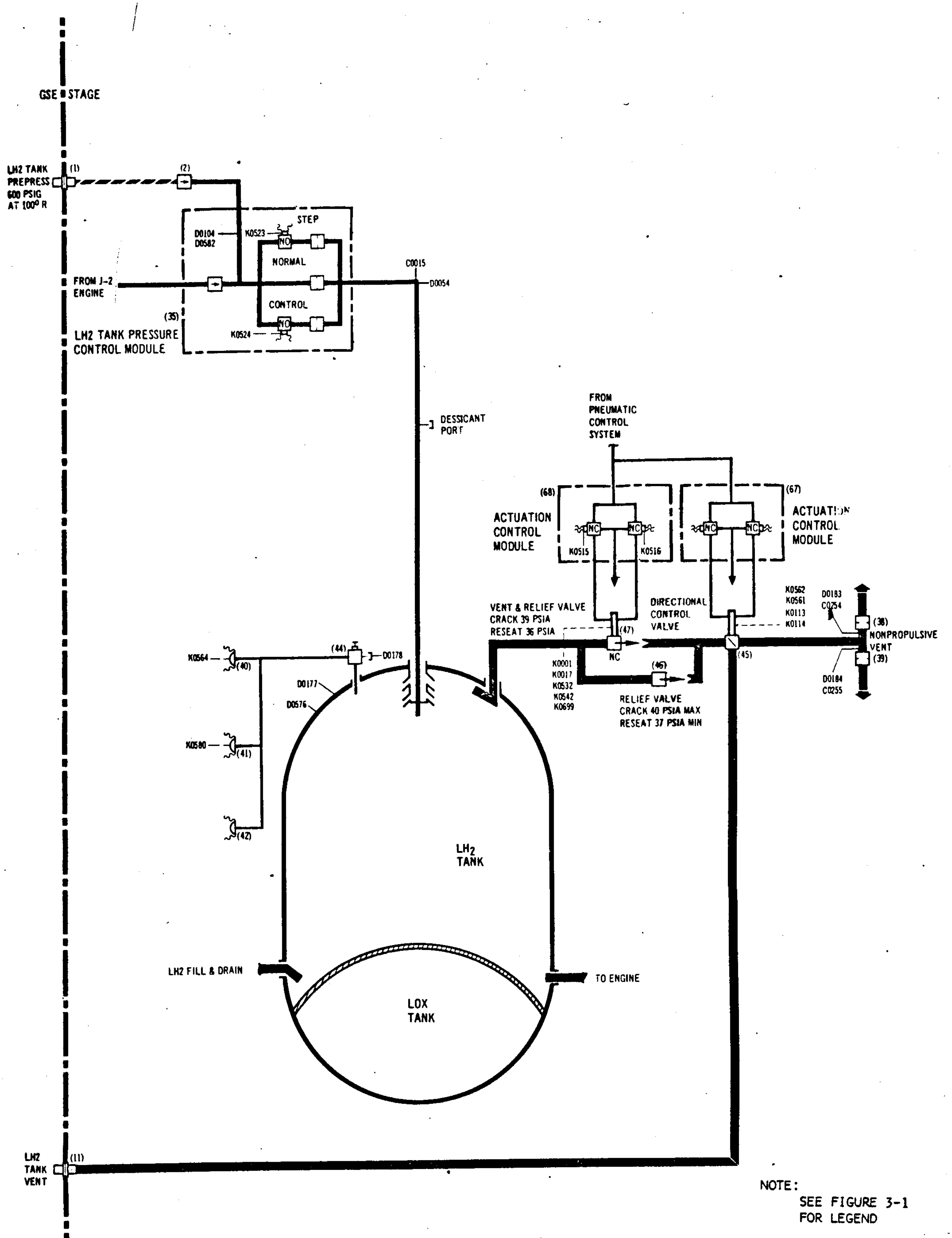
Since S-IVB-206 is an operational stage, LH2 tank skin temperature measurements were not installed. Calculation of the effective thermal conductivity of the stage internal insulation was therefore not possible for this test; however, the computed equivalent total heating rate based on a mass boiloff rate of 38.5 lbm/min, was 445,100 Btu/hr. This heating rate is considered acceptable.

TABLE 8-1
LH2 TANK PREPRESSURIZATION DATA

Prepressurization initiation (sec from SLO)	-110.1
Prepressurization termination (sec from SLO)	-41.6
Prepressurization duration (sec)	68.5
Helium mass used during prepressurization (lbm)	36.4
Time of tank relief (sec from SLO)	N/A
Ullage pressure at termination of prepressurization (psia)	33.6
Ullage pressure at simulated liftoff (psia)	35.0
Ullage pressure at Engine Start Command (psia)	37.5
Ullage pressure at relief valve open (psia)	N/A

TABLE 8-2
LH2 TANK PRESSURIZATION DATA

Number of control cycles	2
Control pressure switch range (psia)	26.8 to 29.1
Ullage pressure at Engine Start Command (psia)	37.6
Ullage pressure at step pressurization (psia)	29.1
Ullage pressure at Engine Cutoff Command (psia)	38.6
Time of step pressurization (sec from ESC)	301.1
GH2 pressurant flowrate--undercontrol (lbm/sec)	0.35
GH2 pressurant flowrate--overcontrol (lbm/sec)	0.63
GH2 pressurant flowrate--step before cutback (lbm/sec)	1.12
GH2 pressurant flowrate--step after cutback (lbm/sec)	1.04
Total GH2 pressurant mass (lbm)	281.6
Time of relief valve opening (sec from ESC)	407
Pressure at relief valve operation (psia)	38.4



NOTE:
SEE FIGURE 3-1 FOR LEGEND

Figure 8-1. LH2 Tank Pressurization System

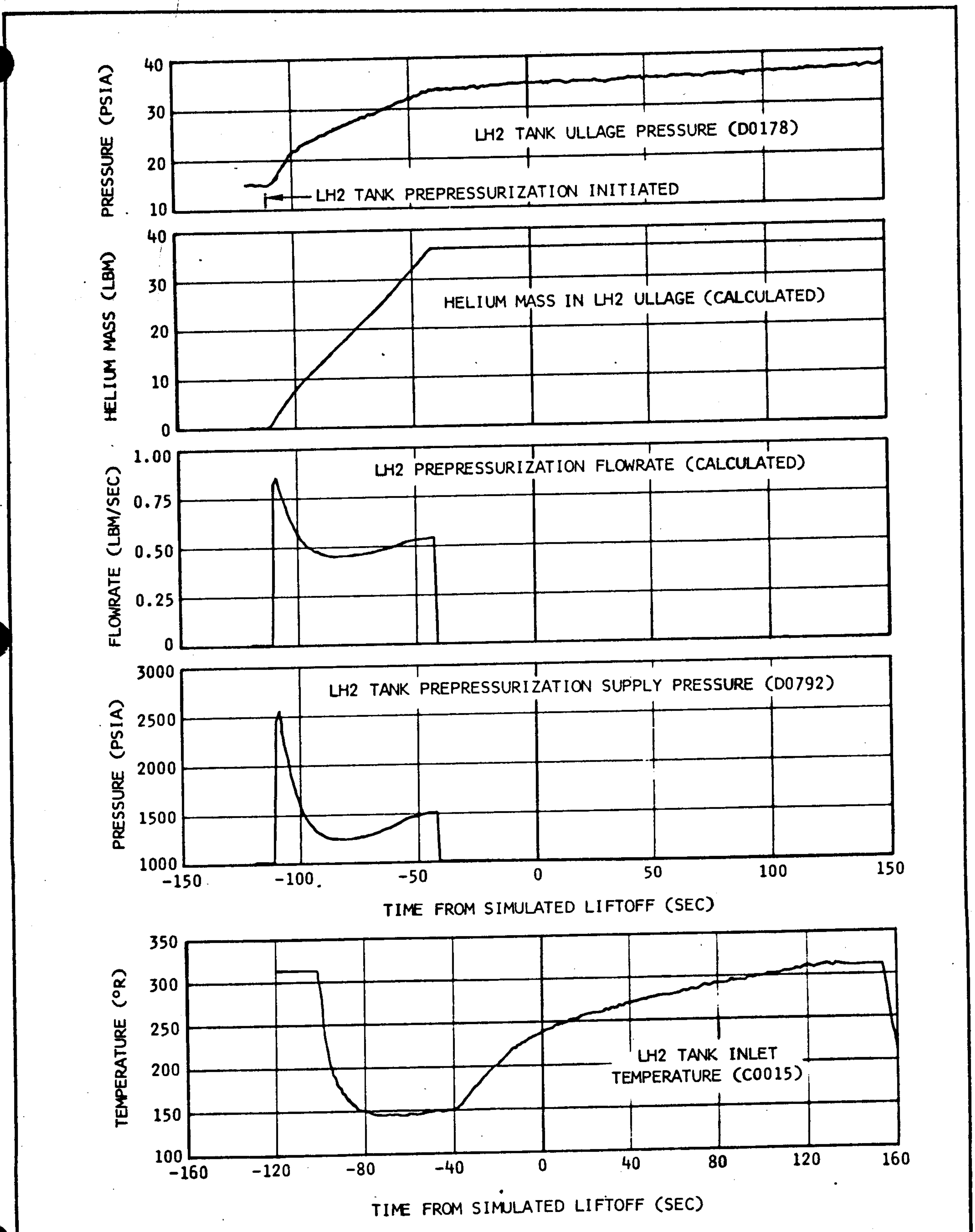


Figure 8-2. LH2 Tank Prepressurization System Performance

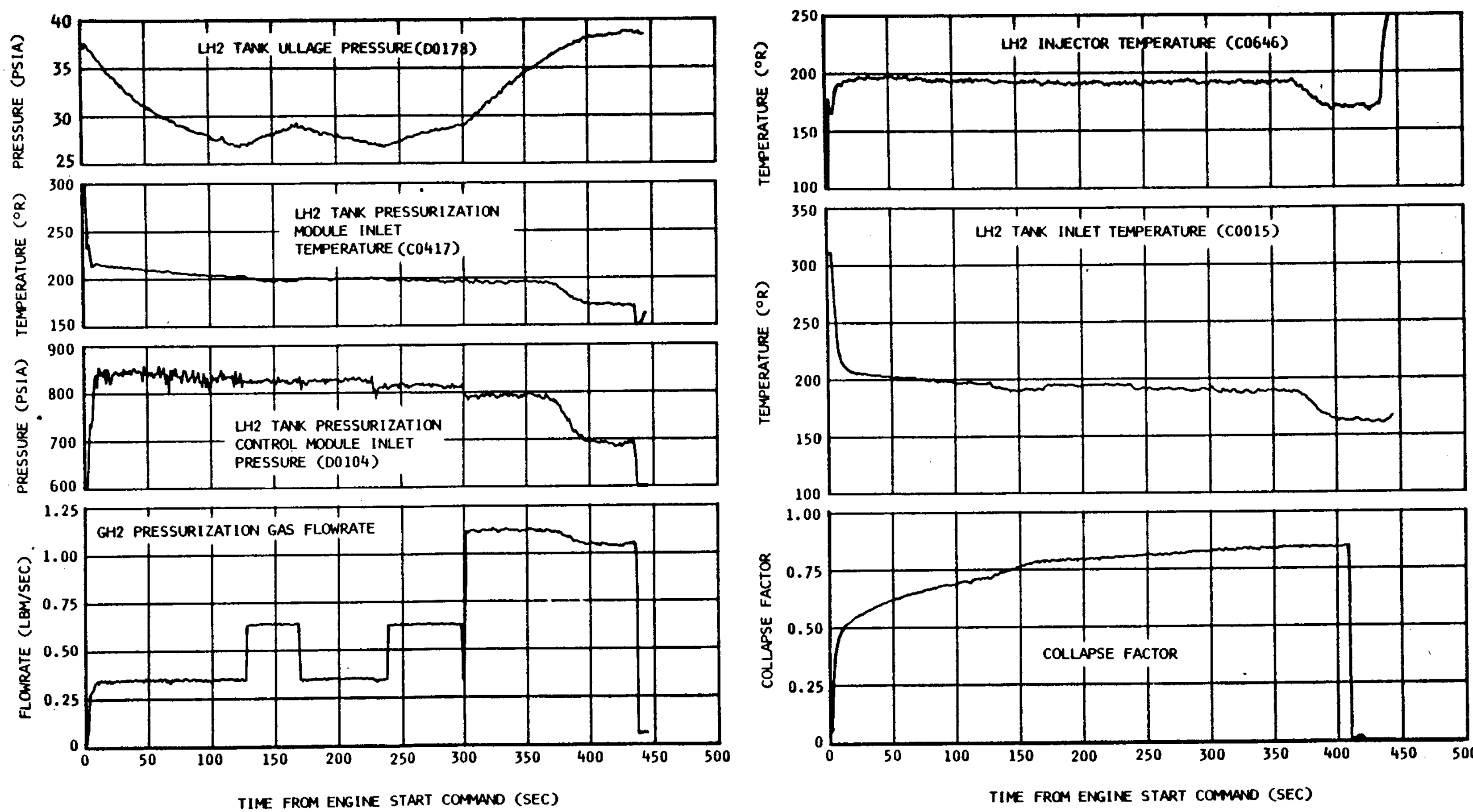


Figure 8-3. LH2 Tank Pressurization System Performance

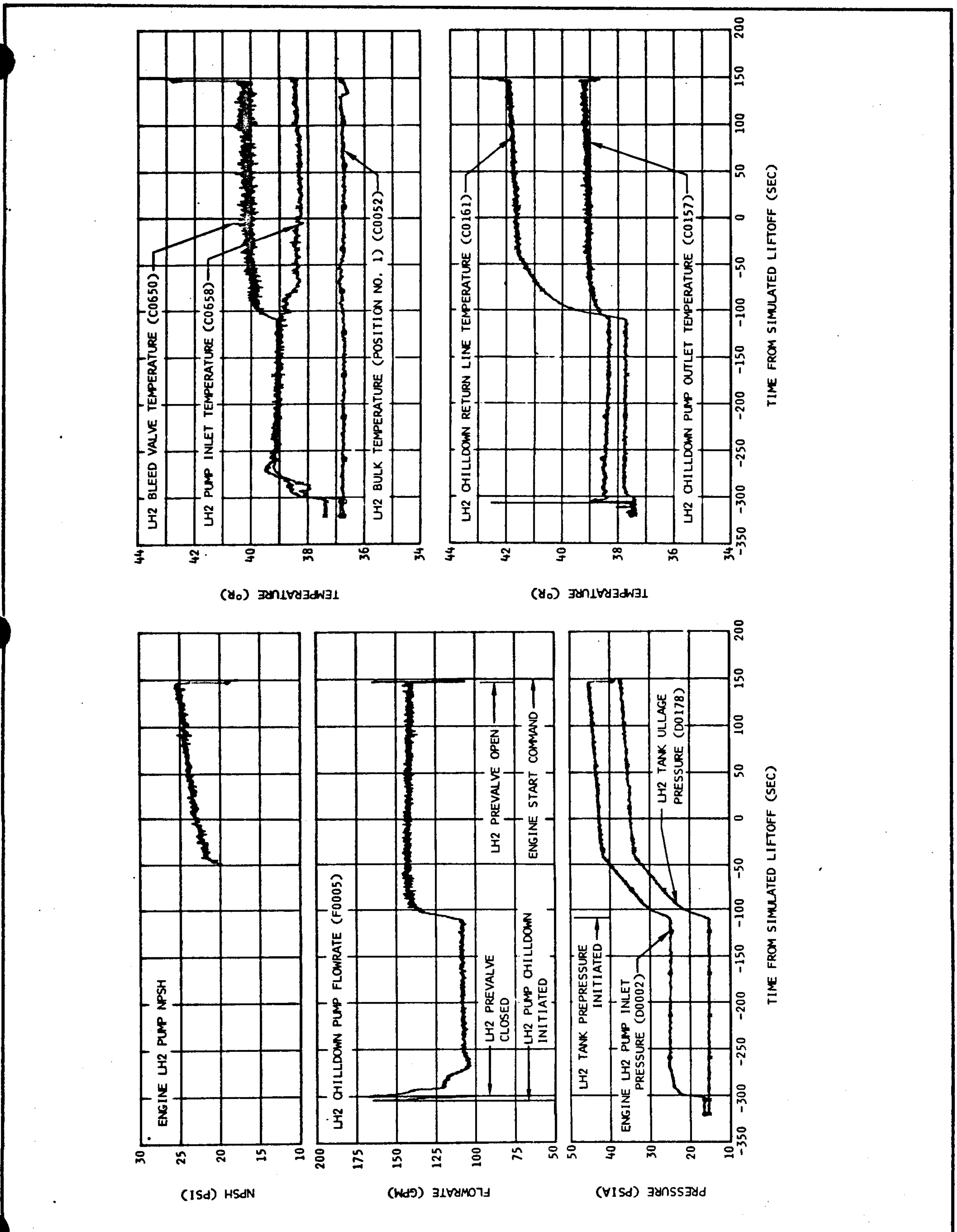


Figure 8-4. LH2 Pump Chilldown

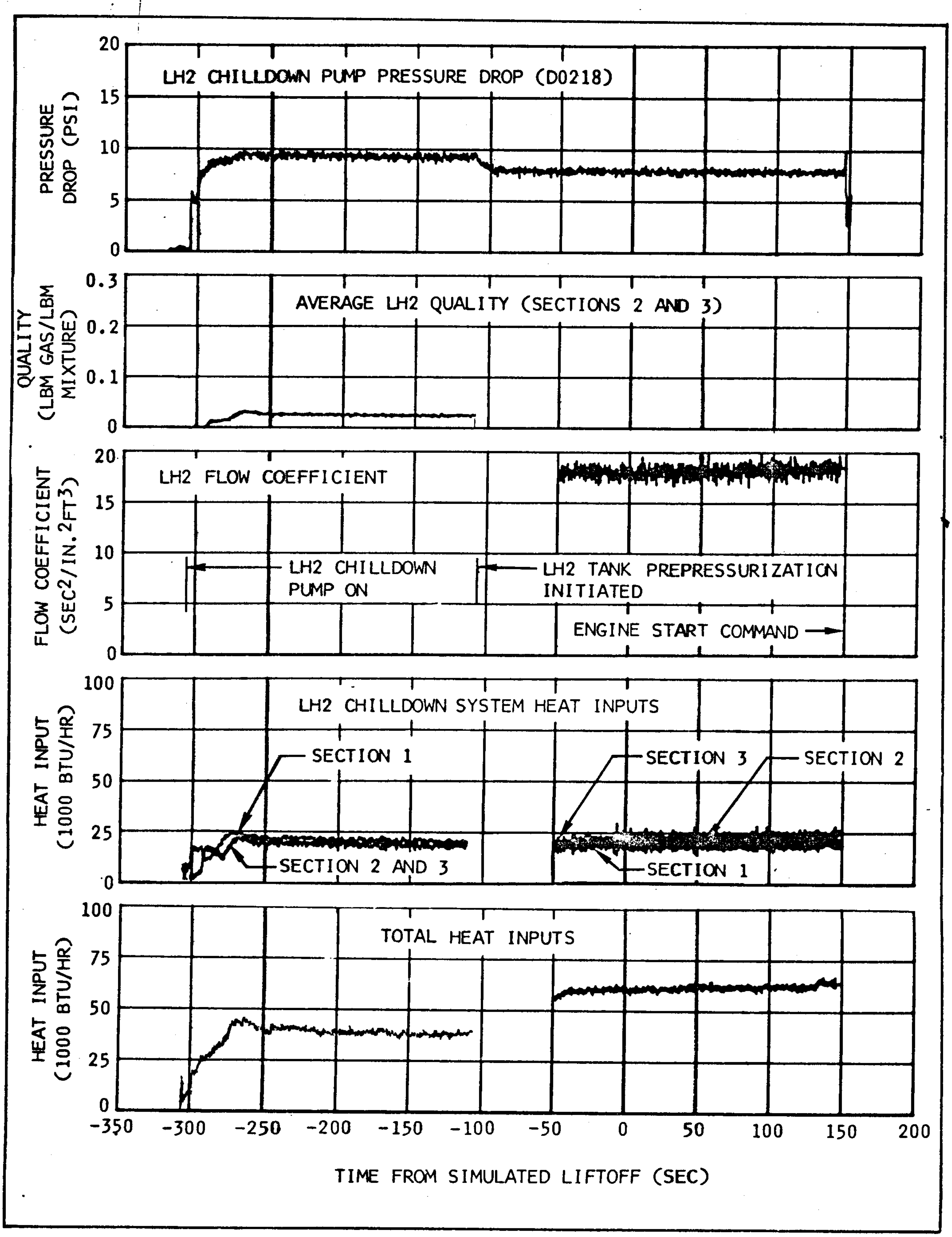


Figure 8-5. LH2 Pump Chilldown Characteristics

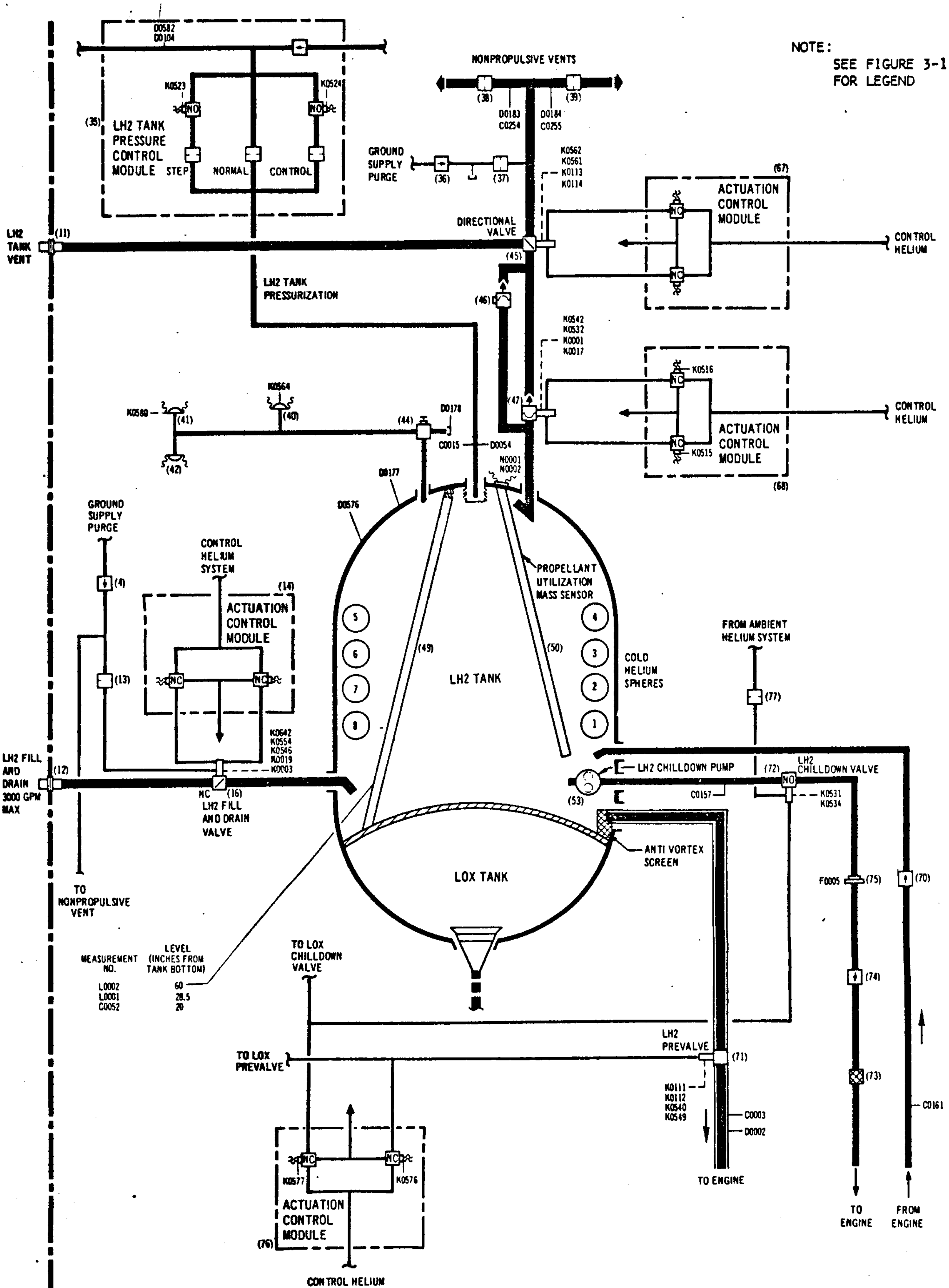


Figure 8-6. LH2 Supply System

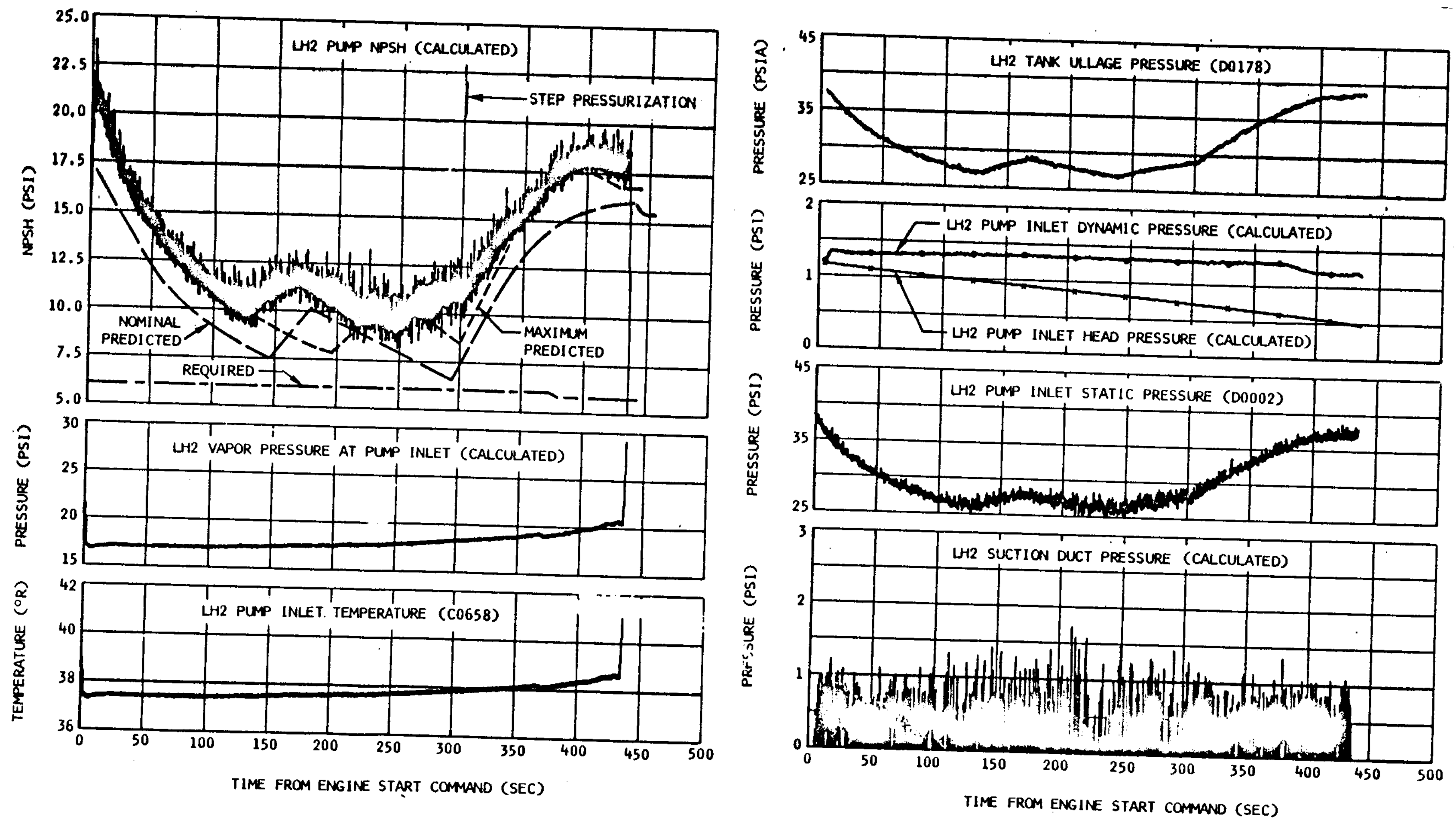


Figure 8-7. LH2 Pump Inlet Conditions

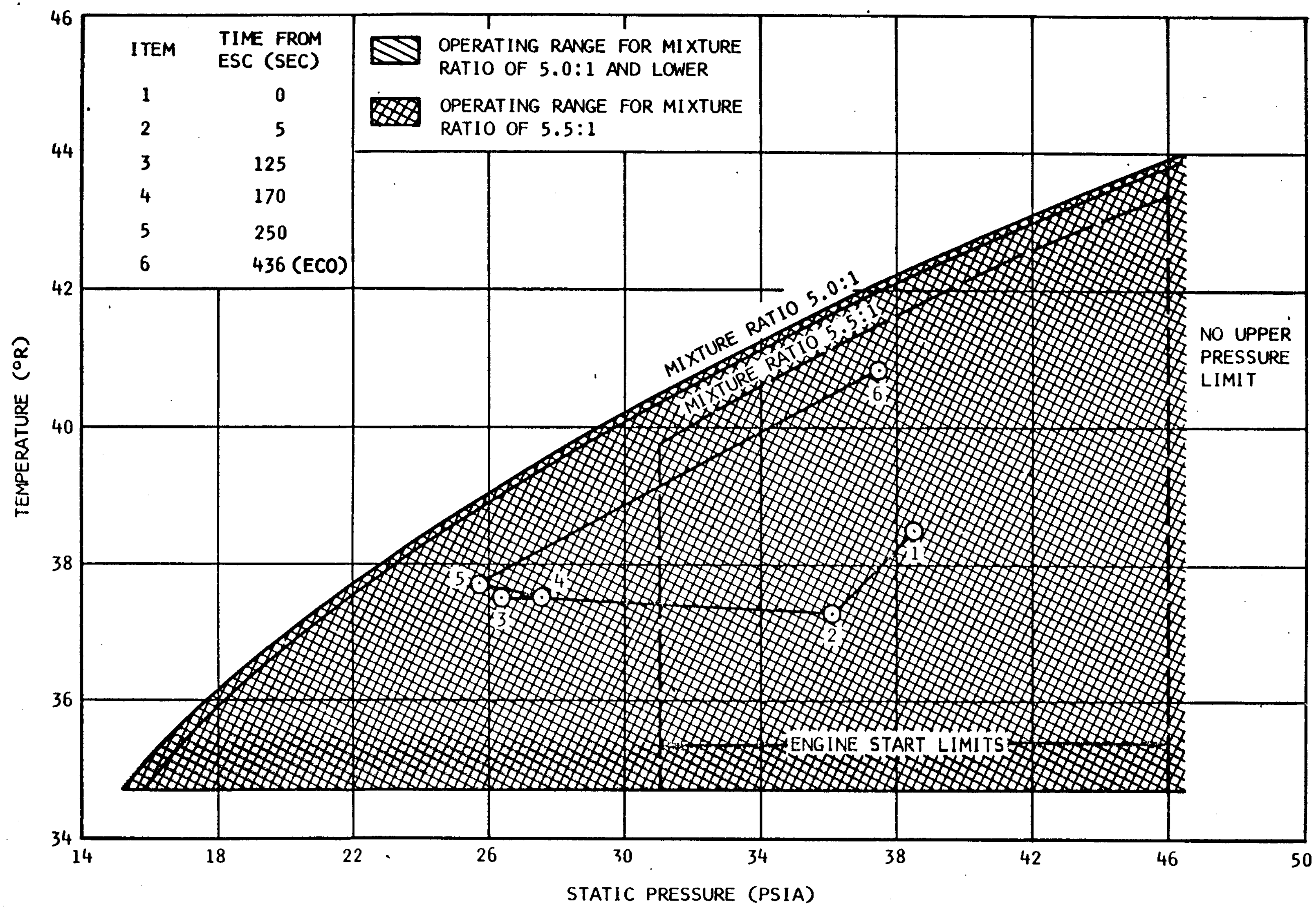


Figure 8-8. LH2 Pump Inlet Conditions During Firing

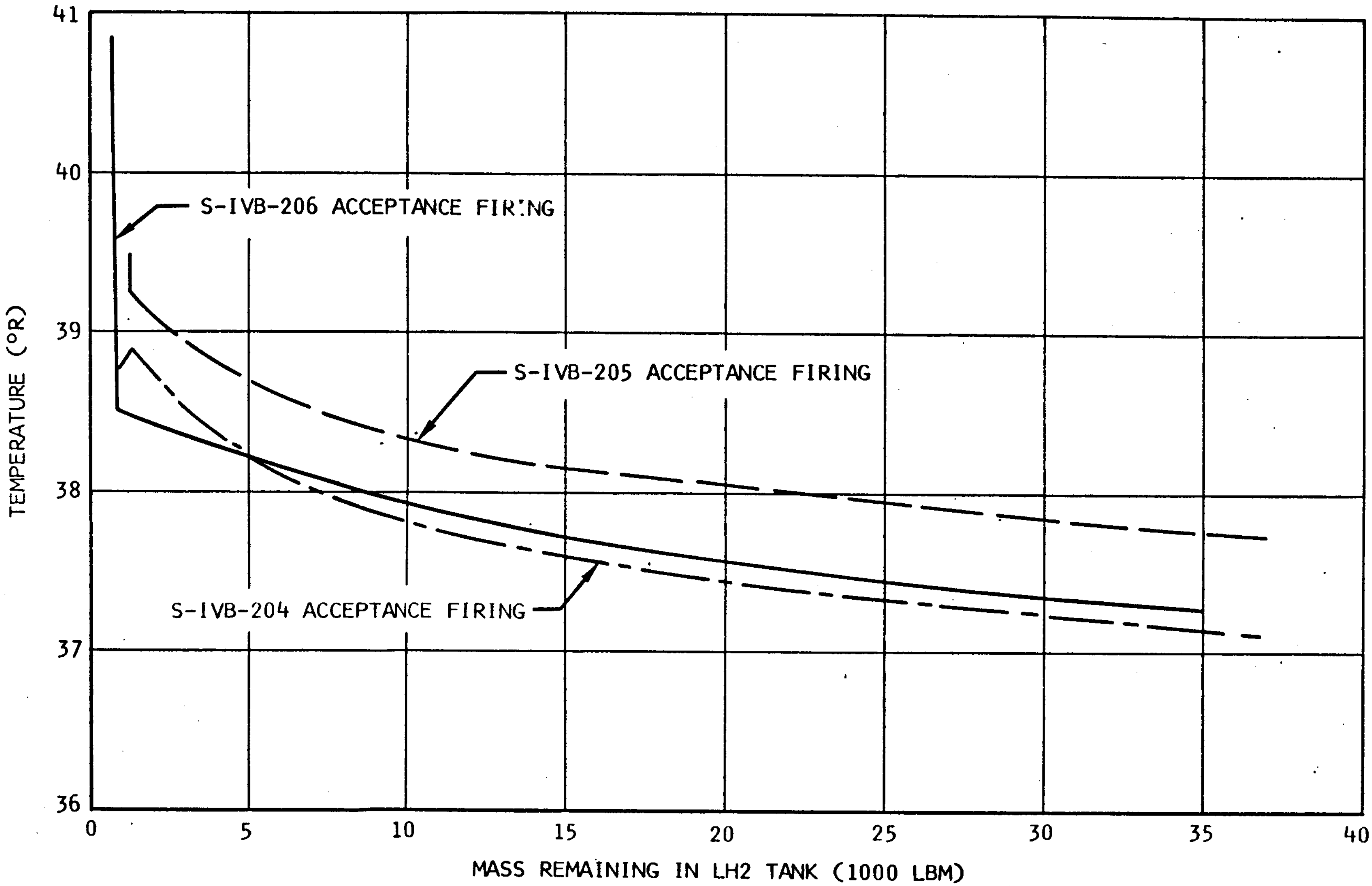


Figure 8-9. Effect of LH2 Tank Mass Level on LH2 Pump Inlet Temperature

9. PNEUMATIC CONTROL AND PURGE SYSTEM

The pneumatic control and purge system (figure 9-1) performed satisfactorily throughout the acceptance firing. The helium supply to the system was adequate for both pneumatic valve control and purging; the regulated pressure was maintained within acceptable limits and all components functioned normally.

9.1 Ambient Helium Supply

The ground support equipment (GSE) helium supply was isolated at approximately 90 sec after simulated liftoff and re-applied immediately after engine cutoff. Conditions at significant times (figure 9-2) are shown in the following table:

Time	Pressure (psia)	Temperature (°R)
Simulated Liftoff (SLO)	3,150	523
SLO +90 sec (GSE isolation)	3,135	520
Engine Start Command (ESC)	3,090	517
Engine Cutoff Command (ECC)	3,010	511

At SLO +90 sec, the pneumatic control sphere contained 1.16 lbm of helium, which was used at a rate of 0.24 scfm from SLO +90 sec until Engine Cutoff Command. The total helium consumed from the time the stage was isolated until Engine Cutoff Command was 0.02 lbm.

9.2 Pneumatic Control

All engine and stage pneumatic control valves responded properly throughout the countdown and acceptance firing. The pneumatic control helium regulator operated satisfactorily and generally maintained an output pressure of 545 to 520 psia; the regulator lockup pressure of 600 psia was attained at approximately SLO +240 sec. This is the first stage on which this setting has been utilized. The system pressure dropped to 470 psia during the start and cutoff transients. These dips have occurred on all past countdowns and since the system pressure recovers quickly, are considered satisfactory.

9.3 Ambient Helium Purges

During the acceptance firing, ten purge functions were satisfactorily accomplished. The pneumatic system was isolated from the GSE at SLO +90 sec; therefore, the purges from the facility supply were discontinued at this time. The purge function characteristics, gas sources, and purging periods are listed in table 9-1.

Throughout the acceptance firing the LOX chilldown motor container pressure was maintained at 40 psia. This demonstrated satisfactory operation of the system; the design range of 37 to 40 psia was achieved.

TABLE 9-1
PURGE FUNCTIONS

PURGE FUNCTION	PURGE HELIUM SOURCE			ORIFICE TYPE/SIZE	NOMINAL FLOWRATE
	GROUND PHASE	BOOST PHASE	S-IVB FLIGHT PHASE		
LOX Tank Vent Valve	Facility*	**		0.024 in.	65 scfm at 3,100 psig
Engine Fuel Turbine Seal Cavity	Stage†	Stage	Stage	††	
Engine LH2 Pump Seal Cavity	Stage	Stage	Stage	††	Total 6.0 scfm at 105-130 psia
Engine LOX Pump Seal	Stage	Stage	Stage	††	
GG GH2 Injector	Stage	Stage	Stage	††	
LOX Childown Pump Module	Stage	Stage	Stage	Sintered	950 $\pm$95 scim at 475 psid
LOX Fill and Drain Valve Housing	Facility	**		Sintered	15 scim 3,200 psig
LH2 Fill and Drain	Facility	**		Sintered	15 scim 3,200 psig
LH2 Nonpropulsive Vent	Facility	**		Sintered	1,728 scim 3,200 psig
LH2 Chilldown Shutoff Valve	Facility	**		Sintered	14 scfm at 3,000 psid

* - GSE console A (DSV-4B-319)
** - Purged from facility until GSE isolation at SLO +90 sec
† - S-IVB regulated pneumatic control supply
†† - Common orifice in engine pump purge control module

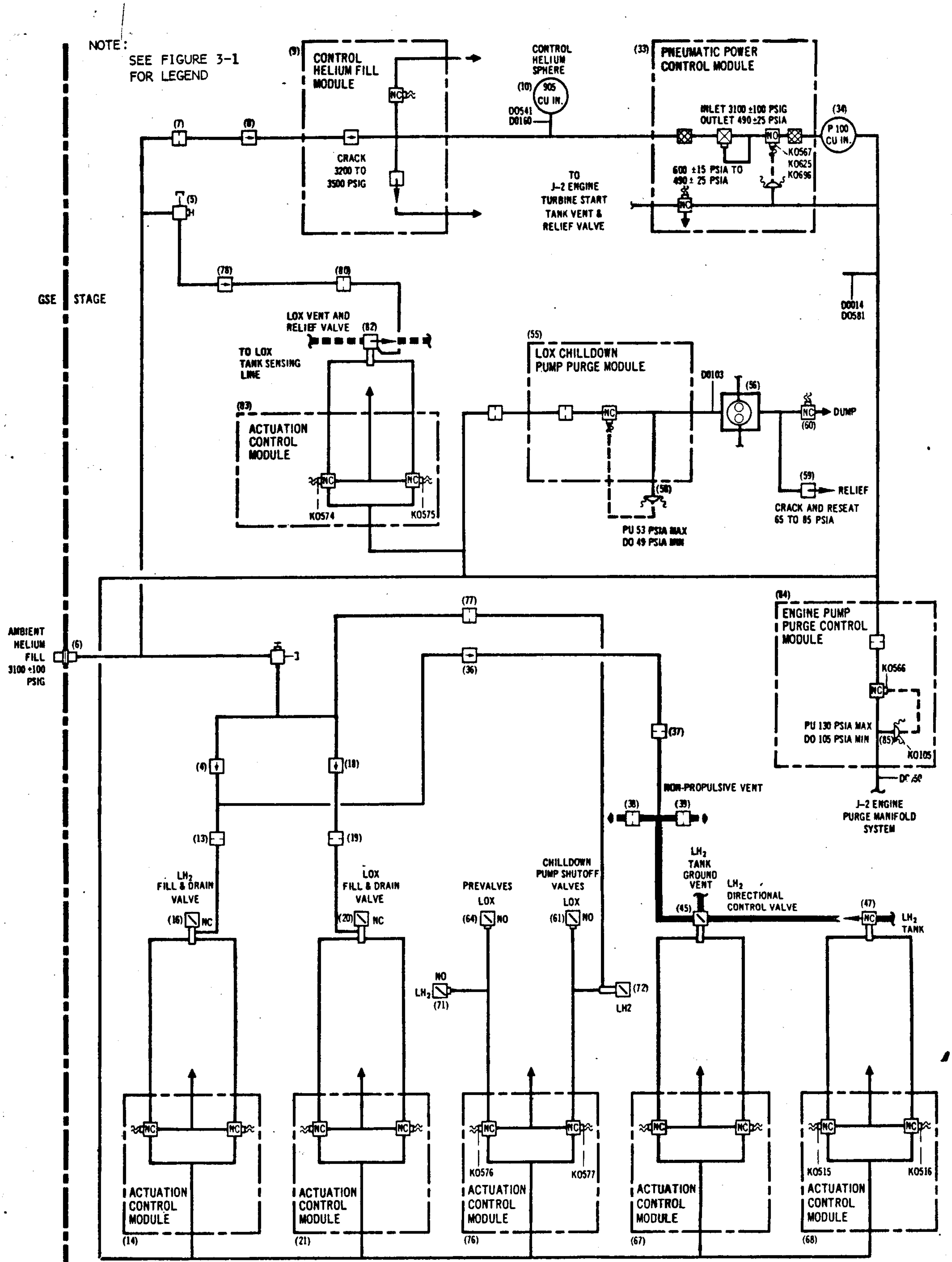


Figure 9-1. Pneumatic Control and Purge System

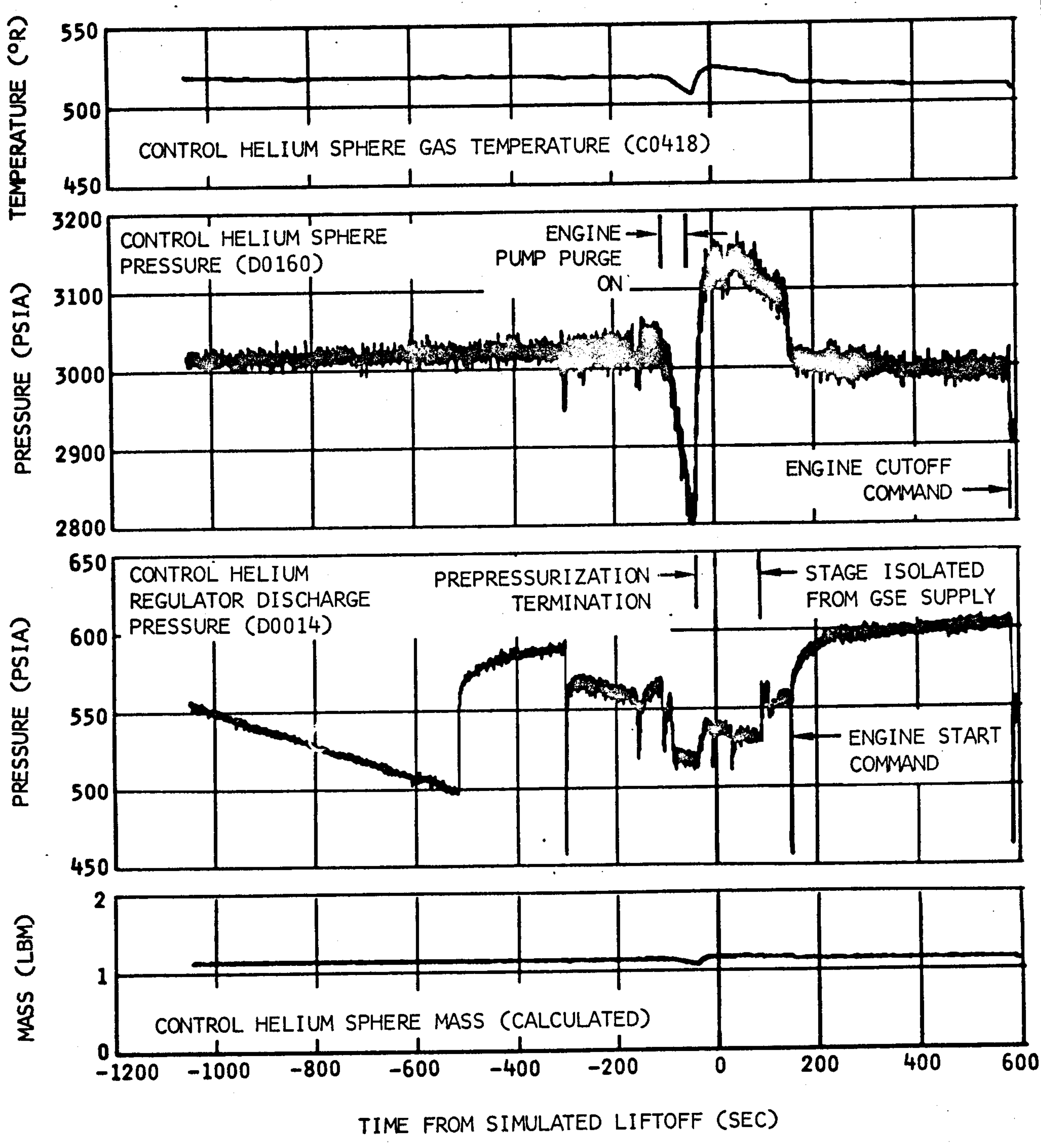


Figure 9-2. Pneumatic Control and Purge System Performance

10. PROPELLANT UTILIZATION SYSTEM

The propellant utilization (PU) system accomplished all the design objectives as listed in DAC Report No. SM-47456, Saturn S-IVB-206 Stage Acceptance Firing Test Plan.

The PU system operated satisfactorily in a closed-loop mode with PU valve cutback occurring at Engine Start Command (ESC) +348.2 sec. Engine mixture ratio (EMR) following PU cutback was 4.81:1 as compared to a predicted value of 4.77:1. Based on extrapolation from the conditions at cutoff, depletion would have occurred with 44 lbm of usable LH2 onboard as compared to a guaranteed value of 575 lbm or less resulting in a PU efficiency of 99.97 percent.

10.1 PU System Calibration

The nominal mass sensor calibration was determined from a combination of empirical and theoretical analysis.

The propellant mass at the lower calibration point was determined from calculated tank volume and predicted propellant density. The corresponding capacitance was evaluated from the vendor's sensor calibration data and previous acceptance firings.

The propellant mass and the capacitance at the upper extremity was determined from the vendor's calibration data and the experimentally determined mass-capacitance relationship of the S-IVB-501 stage analysis.

The LOX and LH2 PU mass sensor calibrations were as follows:

PU Mass Sensors	Picofarads	Mass (lbm)	Location
LOX	282.61 414.80	1,270 195,942	Bottom of Inner Element Top of Inner Element
LH2	972.70 1,189.11	206 44,901	Bottom on Inner Element Top of Inner Element

10.2 Propellant Utilization

10.2.1 Propellant Loading

The propellant loading system indicated propellant loads were 0.347 percent LOX and 0.046 percent LH2 as compared to the desired loads.

Guaranteed PU loading accuracy is ±3.00 percent.

The following is a tabulation of the desired and PU system indicated propellant loading at simulated liftoff (SLO):

	LOX (lbm)	LH2 (lbm)	Total (lbm)
Desired Full Load (Predicted)	193,273	37,046	230,319
Indicated Full Load (PU Reading)	193,669	37,063	230,732
Difference (Indicated Less Desired)	+396 (0.205%)	+17 (0.046%)	+413 (0.180%)

10.2.2 Propellant Mass History

Propellant mass history during the acceptance firing is presented in table 10-1. The propellant load as indicated by the PU system (corrected for nonlinearities) was within 0.348 percent LOX and 0.436 percent LH2 of the actual loads as determined by the flow integral method. Results of the flow integral method of mass determination shall be used to calibrate the PU system capacitance mass sensors to achieve the desired ±1 percent stage loading accuracy for flight.

Flow integral (PA-49) mass values shown in table 10-1 were based on the analysis of propellant flowrates using engine flowmeter data and thrust chamber Delta T data. Statistical methods were used to combine the flow integral mass history results. Residual mass values at engine cutoff were based on point level sensor data. The flow integral method consists of determining the mass flowrate of LOX and LH2 and integrating as a function of time to obtain total consumed mass during firing. The initial full-loaded mass on board is determined by adding the total boiloff, pressurant, and final residuals to total consumed mass as shown in the following table:

Additions to Engine Propellant Consumption	LOX (lbm)	LH2 (lbm)
Propellant Residual	2,216	596
Net Mass Lost Through Boiloff	140	0
GH2 Pressurant Used	--	281
Total	2,356	877

Boiloff values are estimated, since the S-IVB-206 stage does not include ullage temperature measurement instrumentation required to more accurately define ullage mass.

10.2.3 Propellant Residuals

Propellant residuals were obtained at Engine Cutoff Command (ECC) by both the PU system and level sensors. Only one level sensor (L0002) in the LH2 tank and one (L0005) in the LOX tank activated during the acceptance firing. The following table shows the comparison of the PU system and level sensor residuals.

	LOX (lbm)		LH2 (lbm)	
	PU System	Level Sensor	PU System	Level Sensor
Level Sensor (L0005) Activation (SLO +566.6)	10,117	9,838		
Level Sensor (L0002) Activation (SLO +565.88)			2,414	2,256
Engine Cutoff (SLO +586.913)	2,300	2,216	722	596

10.3 System Operation

10.3.1 PU System Nonlinearities

Figures 10-1 and 10-2 indicate the normalized nonlinearity of the LH2 and LOX mass sensor as compared to the flow integral reference. If a smooth curve were drawn through these graphs, it would represent the mass sensor-to-tank mismatch. The LOX mass sensor has a maximum error of approximately 0.65 percent occurring near the 50 percent level of the tank. The LH2 mass sensor has a maximum error of approximately 0.30 percent near the 16 percent level of the tank. Superimposed on these hypothetically smooth mismatch nonlinearity curves are the manufacturing-produced discontinuities in the linearity.

10.3.2 System Response

PU system valve cutback occurred at ESC +348.2 sec. The predicted cutback time was ESC +280 sec. The actual mean level of valve position after cutback was 7.0 deg higher than predicted. The major difference between the actual and predicted PU system response was caused by the LOX turbopump malfunction. The effect of this malfunction on PU system response was isolated by determining the known causes of deviations between the predicted and actual valve response and then assuming the remaining differences were caused by the malfunction (figure 10-3). The following table summarizes these deviations.

Description	Cutback Time Dispersion (sec)	Valve Position Shift (deg)
LOX Turbopump Malfunction	+44.2	+7.0
Open Loop Flowrate Deviation	-8.2	-0.7
Loading Deviation	+5.0	0.0
PA-49 Mass/Capacitance Deviation	+33.8	+2.4
Difference between Predicted and PA-49 Tank-to-Sensor Mismatch Nonlinearities	-6.6	-1.7
Total	+68.2	+7.0

The LOX turbopump malfunction (discussed in paragraph 6.3.2) caused the PU valve cutback time and mean level after cutback to be 44.2 sec later and 7.0 deg higher than predicted; the LOX and LH2 flowrates also verified these results. A comparison of the predicted and actual integrated flowrates indicates that the malfunction caused the cutback time to be

46 sec later than predicted and the average level of the valve position after the cutback transient to be up to 10 deg higher than predicted.

The actual acceptance firing thrust and valve profiles will in general not be applicable to the future flight test of this stage. The turbopump malfunction caused the PU system cutback and response level after cutback to vary significantly from the desired flight response so that a realistic comparison cannot be made. There also was not sufficient time for the cutback transient to settle before the last 70 sec of burn. The thrust slope and variations during the last 40 sec of burn were 15 lbf/sec and 2,000 lbf zero-to-peak (thrust variations are discussed in paragraph 6.3.2).

The effect of the differences between the predicted and actual pump inlet conditions, pressurization rates, and boiloff rates was to decrease cutback time by 8.2 sec and to shift the level of valve position after cutback by -0.7 deg.

Indicated loading deviations are the difference between the actual and the desired indicated loads at ESC. The indicated loading deviations were +396 lbm LOX and +16 lbm LH2. These differences will cause cutback time to occur 5.0 sec later than predicted.

The calibration deviations are defined as the difference between the desired calibration and the actual (derived from PA-49 simulation) calibration as calculated from the indicated and actual (from PA-49) initial loads and residuals. For the S-IVB-206 acceptance firing, the calibration deviations were -0.40 percent LOX and +0.57 percent LH2. The combined effect of these calibration errors was to increase cutback time by 33.8 sec and to shift the mean value of valve position by 2.4 deg.

The desired reference mixture ratio (RMR) for the S-IVB-206 acceptance firing was 4.70:1.0; however, due to the expected EMR shift due to tank-to-sensor mismatch, the bridge gain ratio (BGR) was calibrated to be 4.80:1.0. Calibration deviations affected the BGR such that the actual ratio was 4.847:1.0. The acceptance firing results indicate an actual EMR of 4.78:1.0 near the end of burn.

The effect of the differences between the average of previous acceptance firing tank-to-sensor mismatch results used for the S-IVB-206 prediction and the actual S-IVB-206 acceptance firing tank-to-sensor mismatch was to decrease cutback time by 6.6 sec and to shift the mean value of valve position by -1.7 deg. The PA-49 tank-to-sensor mismatch including manufacturing nonlinearities as derived by use of the PA-49 simulation is given in figures 10-1 and 10-2.

10.3.3 PU Efficiency

The closed-loop PU efficiency was found to be 99.97 percent based on the extrapolation to depletion of all usable propellants. Using engine consumption rates at cutoff, extrapolation resulted in a total usable residual of 43.66 lbm LH2. The propellant consumption flowrates at engine cutoff were 77.825 lbm/sec of LH2 and 374.467 lbm/sec of LOX and represent the summation of the total flow through the engine, the boil-off rates, and the GH2 pressurant flowrate at that time.

PU efficiency in percent is determined by subtracting from one (1.0) the quotient of usable residual propellant (R_u) at depletion cutoff divided by the total propellant load (P_t) and multiplying the result by 100 as shown below.

$$\eta_{PU} = (1.0 - R_u/P_t)\ 100\%$$

10.4 Malfunctions

A malfunction of the LOX turbopump caused the LH2 flowrates to be higher and the LOX flowrates to be lower than predicted. These two combined effects caused the PU valve cutback to occur later and the valve level to be higher after cutback than predicted.

TABLE 10-1
PROPELLANT MASS HISTORY

EVENT	FLOW INTEGRAL MASS (lbm)			PU SYSTEM(1) MASS (lbm)			DEVIATION(2) (lbm)	
	LOX	LH2	TOTAL	LOX	LH2	TOTAL	LOX	LH2
Simulated Liftoff (SLO)	194,095	36,730	230,825	193,420	36,890	230,310	-675	+160
Engine Start(3) Command (ESC) SLO +150.769	194,095	36,730	230,825	193,420	36,890	230,310	-675	+160
PU Valve Cutback ESC +348.2	37,635	7,702	45,337	36,854	7,529	44,383	-781	-173
Engine Cutoff Command ESC +436.144	2,216	596	2,812	2,300	720	3,020	+90	+124

(1) The total mass in the tank as determined by the PU system (corrected for nonlinearity).

(2) Deviation of PU system mass from flow integral mass

(3) The masses shown for ESC are considered the same as the masses at SLO.

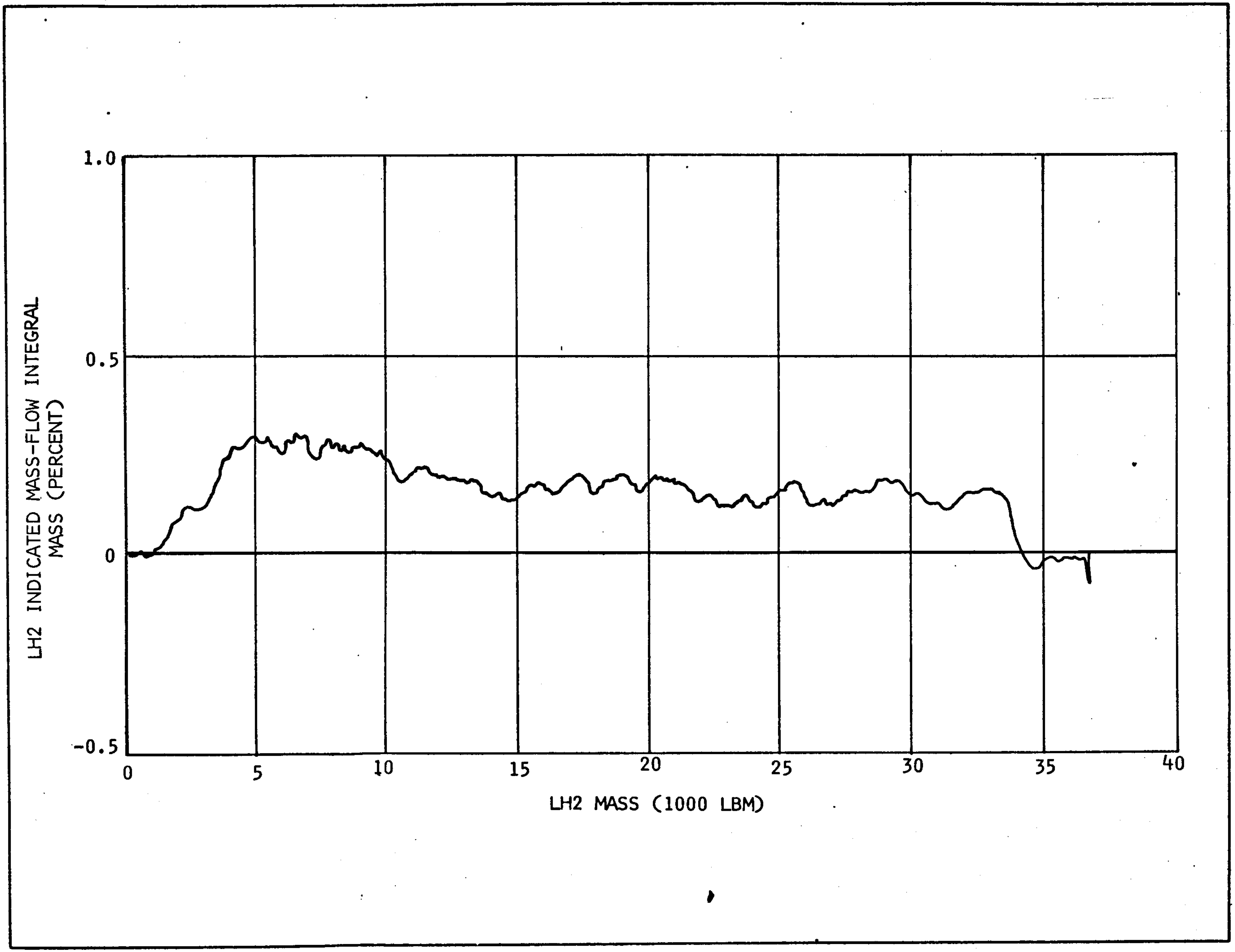


Figure 10-1. Total LH2 Nonlinearity (Normalized)

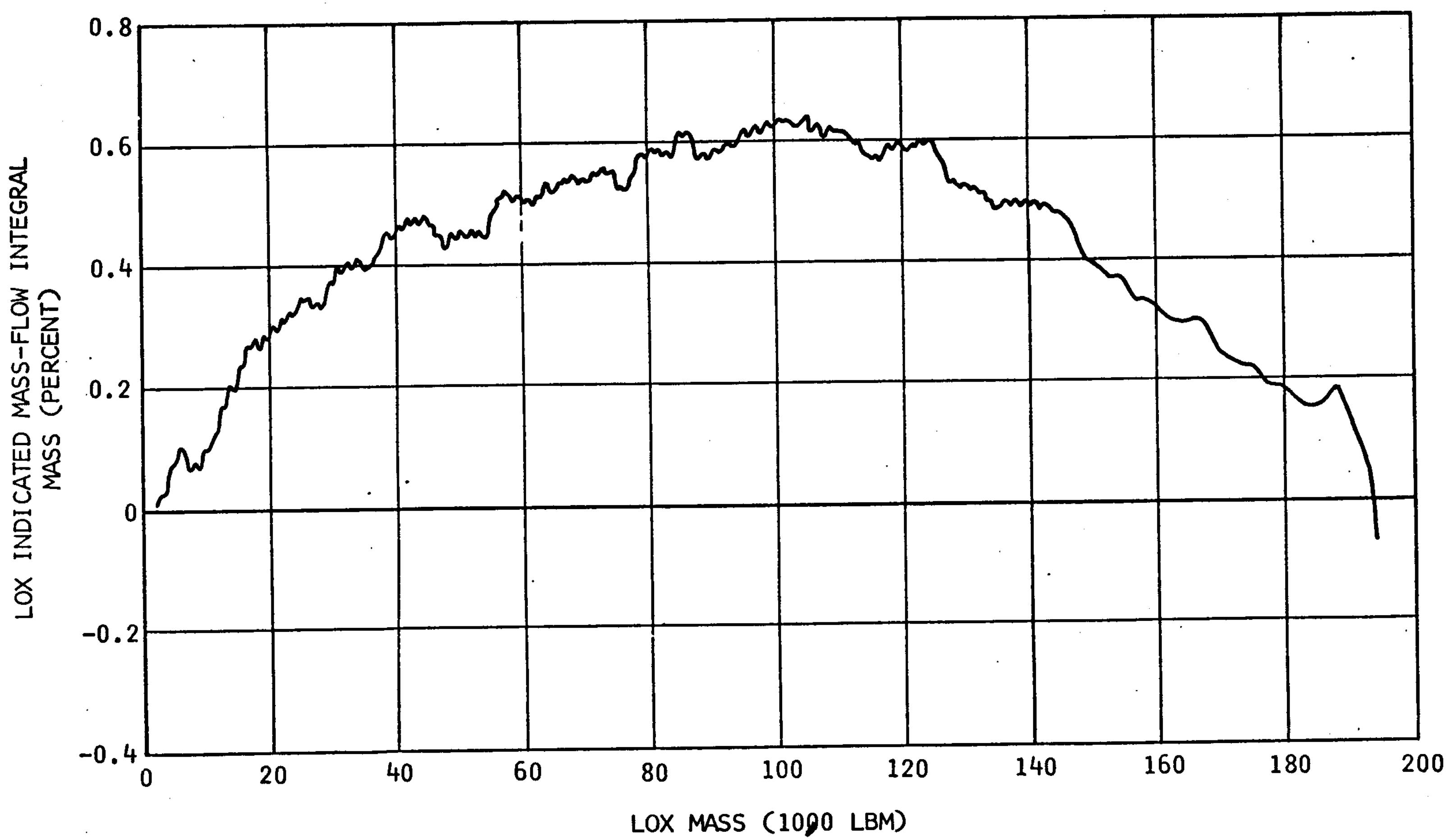


Figure 10-2. Total LOX Nonlinearity (Normalized)

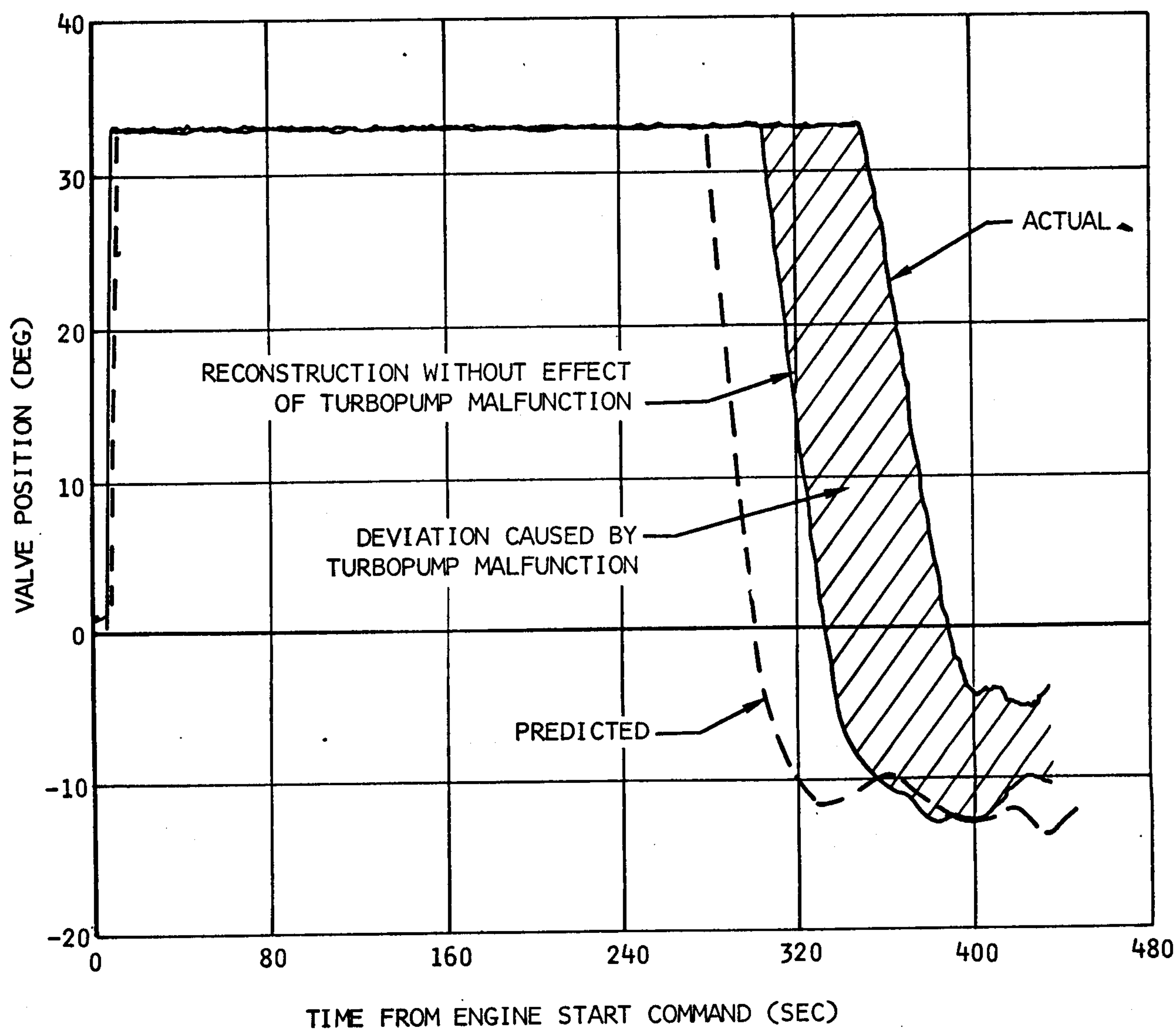


Figure 10-3. Actual vs Predicted PU System Valve Cutback

11. DATA ACQUISITION SYSTEM

The data acquisition system is designed to collect, condition, and transmit information describing the stage environment and performance of the stage systems. Functions assigned to this system and evaluated in this report are specified in the Instrumentation Program and Components List (IPCL), Douglas Drawing No. 1B43559.

In general, the performance of the data acquisition system was very good throughout both the acceptance firing and the engine performance verification firing. A measurement summary is presented in the following table.

Total number of measurements assigned	231
Total number of measurements deleted	56
Total number of active measurements	176
Measurement discrepancies (acceptance firing)	6
Measurement discrepancies (engine verification firing)	8
Total acceptable measurements (acceptance firing)	170
Total acceptance measurements (engine verification firing)	168
Measurement efficiency (acceptance firing)	97.0%
Measurement efficiency (engine verification firing)	95.5%

11.1 Instrumentation System Performance

The instrumentation system performance was very good during both the acceptance firing and the engine performance verification firing. A summary of the instrumentation system performance is presented in table 11-1. Measurement discrepancies that occurred during the acceptance firing and engine performance verification firing are listed, with their qualification comments, in table 11-2. Table 11-3 lists the inactive measurements.

Temperature data for measurement C0052-408 was considered questionable because of its wandering characteristics. Subsequent investigation has not revealed any difficulties and further checks will be made during the post static test.

D0007-401 is a Rocketdyne pressure transducer with a history of calibration degradation. It was removed and replaced by Rocketdyne after the acceptance firing. D0002-403, D0016-425, D0054-410, D0055-424, D0105-403, and D0184-409 are Douglas type strain gage pressure transducers which have been determined to be susceptible to RFI and an ECP is pending to correct this problem. D0055-424 was removed and replaced after the acceptance firing because of invalid data and it was again removed after the engine performance verification firing for the same reason. D0105-403 had a pressure perturbation problem for which an ECP has been approved to relocate the transducer. D0180-424 was removed for recalibration after indicating pressures 2 percent higher than expected during the firing.

RACS calibration for both the acceptance firing (To - 41 min) and the engine performance verification firing (To - 36 min) verified that all measurements having RACS capability were within acceptable tolerance except those mentioned above.

Comparison of the PCM and hardwire (strip chart, GIS, FM) data in tables 11-4 and 11-5 indicates compatible data values.

11.2 Telemetry System Performance

The model 301 PCM assembly was rejected and replaced after acceptance firing because of low inflight multiplexer calibration levels. Retest of the assembly disclosed no malfunction, and the analog-to-digital conversion was within tolerance, although slightly low at full scale. The rejected assembly was readjusted to improve the analog-to-digital conversion linearity at the upper end. No problem was observed during the engine performance verification firing.

Inflight T/M calibration of the model 270 multiplexers was verified on all channels during both firings. Low data points were observed on the CPIBO multiplexer during the acceptance firing; however, postfiring flight calibration was requested and no low data points were observed. During the engine performance verification firing, noise was evident on the reference channels, inflight T/M calibration levels and D0001-401, D0010-401, and D0018-401 strip chart recordings.

Investigation has disclosed that the noise was due to the chilldown inverters being on. Although there has been no significant degradation of flight data, the inflight multiplexer calibration levels indicate data point dispersion when the chilldown inverters are on; therefore, it has been recommended that the inflight calibration be verified during the time that the chilldown inverters are off during checkout.

In the overall analysis, no loss of data was observed due to loss of synchronization or excessive data channel noise.

11.2.1 RF Subsystem Performance

No difficulties were encountered in the performance of the RF subsystem. VSWR's were 1.469:1 for the acceptance firing and 1.473:1 for the engine performance verification firing. The following table presents the RF subsystem performance results.

SYSTEM	PCM/FM	
	ACCEPTANCE FIRING (W)	ENGINE PERFORMANCE VERIFICATION FIRING (W)
PCM/FM transmitter output power (minimum acceptable is 15 W)	16.16	16.4
T/M RF reflected power	0.6	0.6
VSWR (maximum acceptable is 3.1:1)	1.469	1.473

11.2.2 Electromagnetic Compatibility

Interference from other stage systems was not observed; however, the strain gage type pressure transducer exhibited RFI susceptibility (paragraph 11.1).

TABLE 11-1

INSTRUMENTATION SYSTEM PERFORMANCE SUMMARY

FUNCTION	ASSIGNED PER IP & CL	INACTIVE		ACTIVE		DISCREPANCIES		EFFICIENCY (%)	
		ACCEPT FIRING	ENGINE VERIF	ACCEPT FIRING	ENGINE VERIF	ACCEPT FIRING	ENGINE VERIF	ACCEPT FIRING	ENGINE VERIF
Acceleration	0								
Acoustic	0								
Temperature	45	13	13	32	32	1	1	97.8	97.8
Pressure	58	24	24	35	35	5	7	85.8	80.0
Vibration	0								
Flow	4	0	0	4	4	0	0	100.0	100.0
Position	8	5	5	3	3	0	0	100.0	100.0
Events	67	9	9	58	58	0	0	100.0	100.0
Liquid Level	5	1	1	4	4	0	0	100.0	100.0
Volt/Currency/ Freq	29	0	0	29	29	0	0	100.0	100.0
Miscellaneous	13	4	4	9	9	0	0	100.0	100.0
Strains	0								
Speed	2	0	0	2	2	0	0	100.0	100.0
TOTAL	231	56	56	176	176	6	8	97.0	95.5

TABLE 11-2 (Sheet 1 of 4)
T/M MEASUREMENT DISCREPANCIES

MEASUREMENT NO.	PARAMETER	REMARKS
C0003-401	Temp - LH2 Pump Inlet	The data were invalid during the acceptance firing. The transducer was removed and sent to Metrology for recalibration. Out of tolerance probe resistance was indicated and the transducer was rejected and replaced. Measurement indicated properly during the engine performance verification firing.
C0052-408	Temp - Fuel Tank Position 1	The measurement was considered invalid during the engine performance verification firing. The temperature was 3 deg higher than the fuel pump inlet temperature (C0003 and C0658) prior to recirculation (T_o - 307 sec) and became unsteady after T_o - 11 sec. The temperature wandered between 4 to 10 deg higher than the fuel pump inlet temperature during engine burn. Loose contact was suspected; however, investigation has disclosed no loose contact or connection. Measurement shall be followed through post static checkout in VCL.
D0002-403	Press - Fuel Pump Inlet	The measurement was 2 1/2 percent higher than the expected values on RACS and ambient calibration during the engine performance verification firing. The transducer was removed for recalibration; however, it checked out good and was reinstalled. The transducer is a strain gage type (1B40242) and RFI susceptibility is suspected. ECP to correct RFI problems has been approved. With no RF power on, the transducer checked out well within tolerance of 2 percent during DDA Subsystem Test. Measurement shall be followed through post static checkout in VCL.

TABLE 11-2 (Sheet 2 of 4)
T/M MEASUREMENT DISCREPANCIES

MEASUREMENT NO.	PARAMETER	REMARKS
D0007-401	Press - Oxidizer Turbine Inlet	The measurement indicated an ambient pressure which was 20 psia lower than expected during the acceptance firing. The transducer history revealed calibration degradation and it was removed and replaced by Rocketdyne. The measurement was acceptable after replacement for the engine performance verification firing.
D0016-425	Press - Cold Helium Sphere	The transducer failed to indicate proper pressure levels during both the acceptance firing and the engine performance verification firing. The measurement was 9 to 11 percent (300 - 400 psia) higher than the expected values during both tests and is considered as "trend." The transducer is a strain gage type transducer (1B40242) which has shown similar difficulties in previous tests and it has been determined that the problem is RFI susceptibility. An ECP to correct this problem has been approved.
D0054-410	Press - Fuel Tank Inlet	This measurement was 5 percent high on RACS and ambient calibration values during the engine performance verification firing. The CAT-1 calibration was re-evaluated and the measurement was found to be within tolerance of the 20 and 80 percent cal points. Although in tolerance, the measurement was indicating on the high side and this has been attributed to RFI. The transducer is a 1B40242 strain gage type, and the action is the same as D0016.

TABLE 11-2 (Sheet 3 of 4)
T/M MEASUREMENT DISCREPANCIES

MEASUREMENT NO.	PARAMETER	REMARKS
D0055-424	Press - Oxidizer Tank Inlet	For the acceptance firing, the transducer pressure level remained high after engine cutoff, and the transducer was removed from the stage. Upon recalibration, the transducer revealed high contact resistance, indicating extreme wiper wear, and the transducer was replaced. The measurement was also invalidated for the engine performance verification firing where negative pressures are indicated. The transducer was removed and sent to Metrology for recalibration. It was found to be defective and replaced.
D0105-403	Press - LOX Tank Press Mod He Gas	The measurement was invalid during the acceptance firing. RACS calibration levels were low and lower than expected pressure levels were experienced throughout the test. No action was taken to remove and recalibrate this transducer because previous recalibration of this measurement on other stages with identical difficulties have always shown the transducer to be good. An ECP to relocate the transducer has been approved to relieve pressure perturbation problems. The transducer is also susceptible to RFI and the action is the same as D0016. The measurement was also invalid during the engine performance verification with similar difficulties existing.
D0180-424	Press - Oxid Tank Ullage EDS 2	The ambient pressure indicated 2 percent higher than the expected value during the engine performance verification firing. The transducer was removed for recalibration and its linearity was found to be out of tolerance. The transducer was rejected and replaced.

TABLE 11-2 (Sheet 4 of 4)
T/M MEASUREMENT DISCREPANCIES

MEASUREMENT NO.	PARAMETER	REMARKS
D0184-409	Press - LH2 Tank Non-Prop Vent-2	RACS and ambient pressure levels were higher than the expected calibration values during the acceptance firing. Measurements were approximately 3 percent higher than expected. Transducer is a strain gage type transducer (1B40242) susceptible to RFI and correction is pending. With no RF power on, this measurement checked out well within tolerance during the DDA Subsystem Test. The same difficulties were experienced during the engine performance verification firing.

TABLE 11-3 (Sheet 1 of 5)
INACTIVE MEASUREMENTS

MEASUREMENT NO.	T/M CHANNEL NO.	PARAMETER	REASON
C0007-401	DP1B0-17L05	Temp - Engine Control Helium	Open - Hardwire reqm't - T/M disconnected
C0050-401	CP1B0-11-03 DP1B0-11-03	Temp - Hydr Pump Inlet Oil	Open - Hardwire reqm't - T/M disconnected
C0102-411	DP1B0-02-05	Temp - Fwd Battery 1	Simulated - Primary battery not installed
C0103-411	DP1B0-02-06	Temp - Fwd Battery 2	Simulated - Primary battery not installed
C0104-404	DP1B0-11-10	Temp - Aft Battery 1	Simulated - Primary battery not installed
C0105-404	DP1B0-14-10	Temp - Aft Battery 2	Simulated - Primary battery not installed
C0166-414	DP1B0-20L01	Temp - He Sphere Gas, Mod 1 (APS)	Simulated - APS not installed
C0167-415	DP1B0-20L02	Temp - He Sphere Gas, Mod 2 (APS)	Simulated - APS not installed
C0168-414	CP1B0-11-04 DP1B0-11-04	Temp - Oxid Tank Outlet, Mod 1 (APS)	Simulated - APS not installed
C0169-415	CP1B0-11-05 DP1B0-11-05	Temp - Oxid Tank Outlet, Mod 2 (APS)	Simulated - APS not installed
C0170-414	CP1B0-11-06 DP1B0-11-06	Temp - Fuel Tank Outlet, Mod 1 (APS)	Simulated - APS not installed
C0171-415	CP1B0-11-07 DP1B0-11-07	Temp - Fuel Tank Outlet, Mod 2 (APS)	Simulated - APS not installed
C0200-401	DP1B0-18L06	Temp - Fuel Injection	Open - Hardwire reqm't - T/M disconnected

TABLE 11-3 (Sheet 2 of 5)
INACTIVE MEASUREMENTS

MEASUREMENT NO.	T/M CHANNEL NO.	PARAMETER	REASON
D0041-403	CP1BO-13-05 DP1BO-13-05	Press - Hydraulic System	No data - Hardwire reqm't - T/M disconnected
D0042-403	DP1BO-06-07	Precs - Reservoir Oil	No data - Hardwire reqm't - T/M disconnected
D0063-414	DP1BO-07-02	Press - Fuel Sply Man, Mod 1 (APS)	Simulated - APS not installed
D0064-414	CP1BO-13-07 DP1BO-13-07	Press - He Reg Inlet, Mod 1 (APS)	Simulated - APS not installed
D0065-414	CP1BO-13-08 DP1BO-13-08	Press - He Reg Outlet, Mod 1 (APS)	Simulated - APS not installed
D0066-415	DP1BO-07-03	Press - Oxid Sply Man, Mod 2 (APS)	Simulated - APS not installed
D0067-415	DP1BO-07-04	Press - Fuel Sply Man, Mod 2 (APS)	Simulated - APS not installed
D0068-415	CP1BO-13-09 DP1BO-13-09	Press - He Reg Inlet, Mod 2 (APS)	Simulated - APS not installed
D0069-415	CP1BO-13-10 DP1BO-13-10	Press - He Reg Outlet, Mod 2	Simulated - APS not installed
D0078-414	CP1BO-17	Press - Attitude Contr Chamber, 1-1	Simulated - APS not installed
D0079-414	CP1BO-18	Press - Attitude Contr Chamber, 1-2	Simulated - APS not installed
D0080-414	CP1BO-19	Press - Attitude Contr Chamber, 1-3	Simulated - APS not installed
D0081-415	CP1BO-20	Press - Attitude Contr Chamber, 2-1	Simulated - APS not installed

TABLE 11-3 (Sheet 3 of 5)
INACTIVE MEASUREMENTS

MEASUREMENT NO.	T/M CHANNEL NO.	PARAMETER	REMARKS
D0082-415	CP1BO-21	Press - Attitude Contr Chamber, 2-2	Simulated - APS not installed
D0083-415	CP1BO-22	Press - Attitude Contr Chamber, 2-3	Simulated - APS not installed
D0084-414	DP1BO-07-05	Press - Oxid Sply Man, Mod 1 (APS)	Simulated - APS not installed
D0089-414	DP1BO-07-07	Press - Fuel Tank Ullage, Mod 1 (APS)	Simulated - APS not installed
D0090-414	DP1BO-07-08	Press - Oxid Tank Ullage, Mod 2 (APS)	Simulated - APS not installed
D0091-415	DP1BO-07-09	Press - Fuel Tank Ullage, Mod 2 (APS)	Simulated - APS not installed
D0092-415	DP1BO-07-10	Press - Oxid Tank Ullage, Mod 2 (APS)	Simulated - APS not installed
D0093-414	DP1BO-08-01	Press - Fuel Tank Outlet, Mod 1 (APS)	Simulated - APS not installed
D0094-414	DP1BO-08-02	Press - Oxid Tank Outlet, Mod 1 (APS)	Simulated - APS not installed
D0095-415	DP1BO-08-03	Press - Oxid Tank Outlet, Mod 2 (APS)	Simulated - APS not installed
D0096-415	DP1BO-08-04	Press - Fuel Tank Outlet, Mod 2 (APS)	Simulated - APS not installed
G0003-401	CP1BO-23-03 DP1BO-23-03	Posit - Main LOX Valve	Simulated - Hardwire reqm't
G0004-401	CP1BO-23-04 DP1BO-23-04	Posit - Main LH2 Valve	Simulated - Hardwire reqm't

TABLE 11-3 (Sheet 4 of 5)
INACTIVE MEASUREMENTS

MEASUREMENT NO.	T/M CHANNEL NO.	PARAMETER	REMARKS
G0005-401	DP1BO-08-09	Posit - Gas Generator Valve	Simulated - Hardwire reqm't
G0008-401	CP1BO-23-05 DP1BO-23-05	Posit - LOX Turbine Bypass Valve	Simulated - Hardwire reqm't
G0009-401	DP1BO-08-10	Posit - GH2 Start Tank Valve	Simulated - Hardwire reqm't
K0020-401	CP1BO-09R01N10	Event - ASI LOX Valves, OPEN	No data - Computer reqm't
K0116-401	CP1BO-09R02N10	Event - Gas Gen Valve, CLOSED	No data - Computer reqm't
K0119-401	CP1BO-09R03N06	Event - Main LH2 Valve, CLOSED	No data - Computer reqm't
K0121-401	CP1BO-09R03N08	Event - Main LOX Valve, CLOSED	No data - Computer reqm't
K0123-401	CP1BO-09R03N10	Event - Start Tank Disch Valve, CLOSED	No data - Computer reqm't
K0126-401	CP1BO-09R04N01 DP1BO-09-04Y01	Event - LOX Bleed Valve, CLOSED	No data - Computer reqm't
K0127-401	CP1BO-09R04N02 CP1BO-09-04Y02	Event - LH2 Bleed Valve, CLOSED	No data - Computer reqm't
K0128-404	DP1BO-22	Event - Switch Selector	No data - Computer reqm't
L0007-403	CP1BO-11-08 DP1BO-11-08	Level - Reservoir Oil	Simulated - Hardware reqm't
N0037-414	CP1BO-23-07 DP1BO-23-07	Misc - Qty Oxid Tank, Mod 1 (APS)	Simulated - APS not installed

TABLE 11-3 (Sheet 5 of 5)
INACTIVE MEASUREMENTS

MEASUREMENT NO.	T/M CHANNEL NO.	PARAMETER	REMARKS
N0038-415	CP1BO-23-08 DP1BO-23-08	Misc - Qty Oxid Tank, Mod 2 (APS)	Simulated - APS not installed
N0039-414	CP1BO-23-09 DP1BO-23-09	Misc - Qty Oxid Tank, Mod 1 (APS)	Simulated - APS not installed
N0040-415	CP1BO-23-10 DP1BO-23-10	Misc - Qty Fuel Tank, Mod 1 (APS)	Simulated - APS not installed

TABLE 11-4 (Sheet 1 of 4)
TELEMETRY TO HARDWIRE DATA COMPARISON - ACCEPTANCE FIRING (T_o +515 SEC)

PARAMETER	T/M		H/W			
	NMN	PCM	NMN	GIS	S/C	F/M
Temp - LH2 Turbine Inlet	C0001	1,688	C0755	1,675	---	1,766
Temp - LH2 Pump Inlet	C0003	36.6	C0658	39.6	39.74	**
Temp - LOX Pump Inlet	C0004	166.5	C0659	166.3	166.6	167
Temp - GH2 Start Bottle	C0006	199.0	C0649	197.0	219	---
Temp - Electrical Control Ass'y	C0011	549	C0657	542	---	---
Temp - LOX Tank He Inlet	C0016	356	C0662	360	---	---
Temp - LOX Pump Discharge	C0133	171.6	C0648	171.8	---	171.7
Temp - LH2 Pump Discharge	C0134	52.4	C0644	51.9	---	52.2
Temp - Thrust Chamber Jacket	C0199	121	C0645	126	132	---
Temp - Cold He Sphere No. 4	C0210	38.0	C0661	41.0	41.0	---
Press - Thrust Chamber	D0001	781	D0524 D0544	780 ---	758 ---	--- 775
Press - LH2 Pump Inlet	D0002	33.8	D0536	35	32.75	33
Press - LOX Pump Inlet	D0003	38.4	D0537	39	39.5	39.5

* Data taken at T_o + 211 - 214 sec.

** Data invalid due to hardwire instrumentation malfunction.

*** PCM data invalid for reason specified in table 11-2.

TABLE 11-4 (Sheet 2 of 4)
TELEMETRY TO HARDWIRE DATA COMPARISON - ACCEPTANCE FIRING (T_o +515 SEC)

PARAMETER	T/M		H/W			
	NMN	PCM	NMN	GIS	S/C	F/M
Press - Main LH2 Injector	D0004	845	D0518	849	---	845
Press - LH2 Pump Discharge	D0008	1,199	D0516	1,209	---	1,230
Press - LOX Pump Discharge	D0009	1,057	D0522	1,039	---	1,050
Press - GG Chamber	D0010	680	D0530	681	---	670
Press - Cont He Reg Discharge	D0014	599	D0581	575	593	---
Press - Cold He Sphere	D0016	***	D0542	568	556	---
Press - GH2 Start Bottle	D0017	1,364	D0525	1,402	1,417	1,390
Press - Engine Reg Outlet	D0018	430	D0535	410	419	---
Press - Cont He Supply	D0019	2,232	D0534	2,250	2,220	---
Press - He (amb) Sphere	D0160	3,038	D0541	3,041	3,039	---
Press - LOX Tank Ullage - EDS 1	D0177	35.3	D0539	35.3	35	---
Press - LOX Tank Ullage - EDS 2	D0178	35.2	D0539	35.3	35	---
Press - LH2 Tank Ullage - EDS 1	D0179	39.1	D0540	40	40.25	---

* Data taken at T_o + 211 - 214 sec.

** Data invalid due to hardwire instrumentation malfunction.

*** PCM data invalid for reason specified in table 11-2.

TABLE 11-4 (Sheet 3 of 4)
TELEMETRY TO HARDWIRE DATA COMPARISON - ACCEPTANCE FIRING (T_o +515 SEC)

PARAMETER	T/M		H/W			
	NMN	PCM	NMN	GIS	S/C	F/M
Press - LH2 Tank Ullage - EDS 2	D0180	39.7	D0540	40	40.25	---
Press - Common Bulkhead Int	D0208	0.2	D0545	0.4	-0.3	---
Flowrate - LOX	F0001*	2,950	F0506*	2,865	---	2,904
Flowrate - LH2	F0002*	8,025	F0507*	8,357	---	7,937
Position - Pitch Actuator	G0001	-0.2	G0504	-0.25	-0.05	-0.05
Position - Yaw Actuator	G0002	+0.4	G0505	+0.5	-0.025	-0.03
Position - PU Valve	G0010	1.13	G0503	1.05	---	1.0
Voltage - Engine Control Bus	M0006	29.6	M0514	29.5	29.6	---
Voltage - Engine Ignition Bus	M0007	29.5	M0515	29.7	30.2	---
Voltage - Aft Battery 1	M0014	30.1	M0541	28.4	---	---
Voltage - Aft Battery 2	M0015	57.9	M0540	56.8	56.75	---
Voltage - Fwd Battery 1	M0016	29.9	M0543	28.2	---	---
Voltage - Fwd Battery	M0018	29.3	M0542	28.5	---	---
Current - Fwd Battery 1	M0019	10	M0536	14	---	---

* Data taken at T_o + 211 - 214 sec.

** Data invalid due to hardwire instrumentation malfunction.

*** PCM data invalid for reason specified in table 11-2.

TABLE 11-4 (Sheet 4 of 4)

TELEMETRY TO HARDWIRE DATA COMPARISON - ACCEPTANCE FIRING (T_o +515 SEC)

PARAMETER	T/M		H/W			
	NMN	PCM	NMN	GIS	S/C	F/M
Current - Fwd Battery 2	M0020	4.1	M0537	4.0	---	---
Current - Aft Battery 1	M0021	13	M0534	18	---	---
Current - Aft Battery 2	M0022	42	M0535	45	44	45.4
Speed - LOX Pump	T0001*	8,266	T0502*	---	---	8,655
Speed - LH2 Pump	T0002*	26,630	T0503*	---	---	26,662

* Data taken at T_o + 211 - 214 sec.

** Data invalid due to hardwire instrumentation malfunction.

*** PCM data invalid for reason specified in table 11-2.

TABLE 11-5 (Sheet 1 of 3)

TELEMETRY TO HARDWIRE DATA COMPARISON - ENGINE PERFORMANCE VERIFICATION FIRING (T_o +213 SEC)

PARAMETER	T/M		H/W			
	NMN	PCM	NMN	GIS	S/C	F/M
Temp - LH2 Turbine Inlet	C0001	1,736	C0755	1,731	---	1,788
Temp - LH2 Pump Inlet	C0003	37.4	C0658	37.6	37.68	37.7
Temp - LOX Pump Inlet	C0004	164.7	C0659	164.6	164.9	164.7
Temp - GH2 Start Bottle	C0006	176	C0649	181	182.5	---
Temp - Electrical Control Ass'y	C0011	522	C0657	522	---	---
Temp - LOX Tank He Inlet	C0016	529	C0662	528	---	---
Temp - LOX Pump Discharge	C0133	169.9	C0648	169.7	---	169.8
Temp - LH2 Pump Discharge	C0134	51.2	C0644	50.8	---	50.84
Temp - Thrust Chamber Jacket	C0199	124	C0645	139	131.8	---
Temp - Cold He Sphere No. 4	C0210	35.0	C0661	35.0	34.07	---
Press - Thrust Chamber	D0001	789	D0524 D0544	789 ---	790 ---	--- 799
Press - LH2 Pump Inlet	D0002	30.2	D0536	30	30	28
Press - LOX Pump Inlet	D0003	39.0	D0537	39	39.9	39
Press - Main LH2 Injector	D0004	880	D0518	880	---	893
Press - LH2 Pump Discharge	D0008	1,214	D0516	1,251	---	1,249
Press - LOX Pump Discharge	D0009	1,094	D0522	1,085	---	1,102

TABLE 11-5 (Sheet 2 of 3)

TELEMETRY TO HARDWIRE DATA COMPARISON - ENGINE PERFORMANCE VERIFICATION FIRING (T_o +213 SEC)

PARAMETER	T/M		H/W			
	NMN	PCM	NMN	GIS	S/C	F/M
Press - GG Chamber	D0010	671	D0530	696	---	685
Press - Cont He Reg Discharge	D0014	600	D0581	590	590	---
Press - Cold He Sphere	D0016	2,397	D0542	2,085	2,152	---
Press - GH2 Start Bottle	D0017	1,198	D0525	1,234	1,233	1,232
Press - Engine Reg Outlet	D0018	415	D0535	414	415	---
Press - Cont He Supply	D0019	2,396	D0534	2,424	2,430	---
Press - He (Amb) Sphere	D0160	3,042	D0541	3,046	3,095	---
Press - LOX Tank Ullage - EDS 1	D0177	29.8	D0539	30.2	30	---
Press - LOX Tank Ullage - EDS 2	D0178	30.2	D0539	30.2	30	---
Press - LH2 Tank Ullage - EDS 1	D0179	35.7	D0540	36.8	36.5	---
Press - LH2 Tank Ullage - EDS 2	D0180	36.6	D0540	36.8	36.5	---
Press - Common Bulkhead Int	D0208	+0.1	D0545	-0.4	-0.25	---
Flowrate - LOX	F0001	2,933	F0506	2,901	---	2,926
Flowrate - LH2	F0002	8,045	F0507	8,362	---	7,972
Position - Pitch Actuator	G0001	-0.14	G0504	---	+0.3	-0.2

TABLE 11-5 (Sheet 3 of 3)
TELEMETRY TO HARDWIRE DATA COMPARISON - ENGINE PERFORMANCE VERIFICATION FIRING (T_o +213 SEC)

PARAMETER	T/M		H/W			
	NMN	PCM	NMN	GIS	S/C	F/M
Position - Yaw Actuator	G0002	+0.36	G0505	---	+0.3	-0.2
Position - PU Valve	G0010	0.14	G0503	0.08	0.145	0.13
Voltage - Engine Control Bus	M0006	29.6	M0514	29.6	29.7	29.6
Voltage - Engine Ignition Bus	M0007	29.8	M0515	29.5	30.55	---
Voltage - Aft Battery 1	M0014	29.8	M0541	29.7	---	29.6
Voltage - Aft Battery 2	M0015	58.4	M0540	57.5	59.2	---
Voltage - Fwd Battery 1	M0016	30.3	M0543	30.9	---	30.4
Voltage - Fwd Battery 2	M0018	29.1	M0542	29.2	---	29.3
Current - Fwd Battery 1	M0019	10.0	M0536	14.0	---	14
Current - Fwd Battery 2	M0020	4.7	M0537	4.8	---	---
Current - Aft Battery 1	M0021	15.0	M0534	20.0	---	20
Current - Aft Battery 2	M0022	25.0	M0535	---	26.2	25.5
Speed - LOX Pump	T0001	8,458	T0502	---	---	8,722
Speed - LH2 Pump	T0002	26,626	T0503	---	---	26,742

12. ELECTRICAL POWER AND CONTROL SYSTEMS

12.1 Electrical Control System

All control system events that function as a direct result of a switch selector command performed satisfactorily as shown in the sequence of events (section 5). The system performance of non-programmed events is presented in the following paragraphs.

12.1.1 J-2 Engine Control System

All event measurements verified that the engine control system responded properly to the engine start and cutoff commands. The Engine Start Command (ESC) was given by the switch selector 150.761 sec after simulated liftoff. Engine cutoff was initiated 587.153 sec after simulated liftoff.

The engine cutoff (non-programmed) sent a signal to the prevalve delay timer. The timer output occurred 423 ms later, within specified limits (425 $\pm$25 ms). The main LOX and LH2 valves had closed prior to timer output.

12.1.2 Range Safety System

During the engine burn phase, the range safety system was employed for verification of performance integrity. Evaluation of the data verified that the range safety system performed satisfactorily.

12.1.3 Control Pressure Switches

A review of the event and pressure measurements verified that each control item functioned properly. Each pressure switch and those associated measurements were evaluated and a description of their performance is presented in the following paragraphs.

K0102 LOX Prepress Flight Switch-Energized
D0179, D0180 Oxide Tank Ullage EDS 1 and 2 Pressure

The above measurements verified the satisfactory completion of its designed purpose. The pressure limits of the switch are 37 - 39.5 psia.

K0105 Engine Pump Purge Control Regulator Backup Pressure Switch De-energized
(K0566) Engine Pump Purge Control Module Solenoid Valve Energized
D0050 Engine Pump Purge Regulator Pressure

Switch K0105 was de-energized throughout the acceptance firing and the pressure D0050 never reached the actuation pressure of 130 psia.

K0131 LOX Childown Purge Switch De-energized
D0103 He to LOX Motor Control Pressure
(K0565) LOX Pump Purge Control Motor Valve-Energized

The above measurements verified that this pressure switch was functioning properly. The pressure limits of the switch is 49 - 54 psia.

K0156 LOX Tank Regulator Backup Pressure Switch-Energized
D0225 Pressure-Cold Helium Control Valve Inlet

The above measurements show that the switch was de-energized during the test and the pressure did not attain the actuation pressure of 465 psia.

12.1.4 Vent Valves

The LOX and LH2 vent valves are commanded open and close by GSE, bypassing the switch selector. The vent valves responded to these commands. These valves are normally closed during simulated powered flight. The LOX and LH2 vent valves performed satisfactorily during acceptance firing. Measurements reviewed are listed below.

K0001 (K0532) Fuel Tank Vent Valve Closed
K0017 (K0542) Fuel Tank Vent Valve Open
D0177, D0178 Fuel Tank Ullage EDS 1 and 2 Pressure
K0002 (K0533) Oxidizer Tank Vent Valve Closed
K0016 (K0543) Oxidizer Tank Vent Valve Open
D0179, D0180 LOX Tank Ullage EDS 1 and 2 Pressure

12.1.5 Directional Vent Valve

The directional vent valve was commanded to the flight position 30.604 sec prior to simulated liftoff and remained in this position throughout the acceptance firing. This was as expected. The following measurements were reviewed:

K0113 Fuel Tank Directional Vent Valve "C" Closed
K0114 Fuel Tank Directional Vent Valve "D" Closed

12.1.6 Fill and Drain Valves

Prior to simulated liftoff, the fill and drain valves were commanded closed through the umbilical. These valves remained closed throughout the acceptance firing. After firing, the fill and drain valves were opened to drain the remaining propellants. The data review of the following measurements verified that the valves performed as expected to GSE commands.

K0003 (K0554) Fuel Fill and Drain Valve Closed
K0019 (K0546) Fuel Fill and Drain Valve Open
K0004 (K0553) LOX Fill and Drain Valve Closed
K0018 (K0547) LOX Fill and Drain Valve Open

12.1.7 Depletion Sensors

During LOX loading, LOX level sensor No. 1 and No. 3 cycled abnormally to the dry condition after having been submerged. After these periods of cycling, the sensors indicated a wet condition throughout the test. LOX level sensor No. 2 performed as expected.

During LH2 loading, LH2 level sensor No. 1 cycled abnormally four times after stabilizing in the wet condition. Following these abnormal cycles, the level sensor performed satisfactorily. LH2 level sensor No. 2 and No. 3 functioned satisfactorily. See figure 12-1 for history of performance during the acceptance firing.

12.2 APS Electrical Control System

The APS simulator No. 188B was activated for verification of the APS No. 1 and No. 2 engines control functions.

Exhibits of the engine feed valves verify that the electrical control system performed within the prescribed limitations.

Listed are the monitored results:

Meas No.	Function	Specified Min Value	Actual Value
K0132	APS Eng 1-1/1-3 Feed Valves Open	3.2 vdc	4.33
K0133	APS Eng 1-2 Feed Valves Open	3.2 vdc	4.22
K0134	APS Eng 2-1/2-3 Feed Valves Open	3.2 vdc	4.10
K0135	APS Eng 2-2 Feed Valves Open	3.2 vdc	4.15

The specified minimum value of 3.2 vdc indicates that all of the feed valves were open.

12.3 Electrical Power System

The electrical power system performed satisfactorily throughout the acceptance firing.

Battery voltage and current profiles are shown in figures 12-2 and 12-3.

12.3.1 Static Inverter-Converter

The static inverter-converter operated within its required limits during the acceptance firing.

12.3.2 5-Volt Excitation Modules

The performance of the forward No. 1 and No. 2, and aft 5-volt excitation modules was satisfactory during the acceptance firing.

12.3.3 Chilldown Inverters

The chilldown inverters performed satisfactorily during the acceptance firing.

During the operation of the chilldown inverters, some data exhibited approximately 4 percent noise. It has been established the source of the noise was in the chilldown inverters. An investigation is now underway to determine the cause.

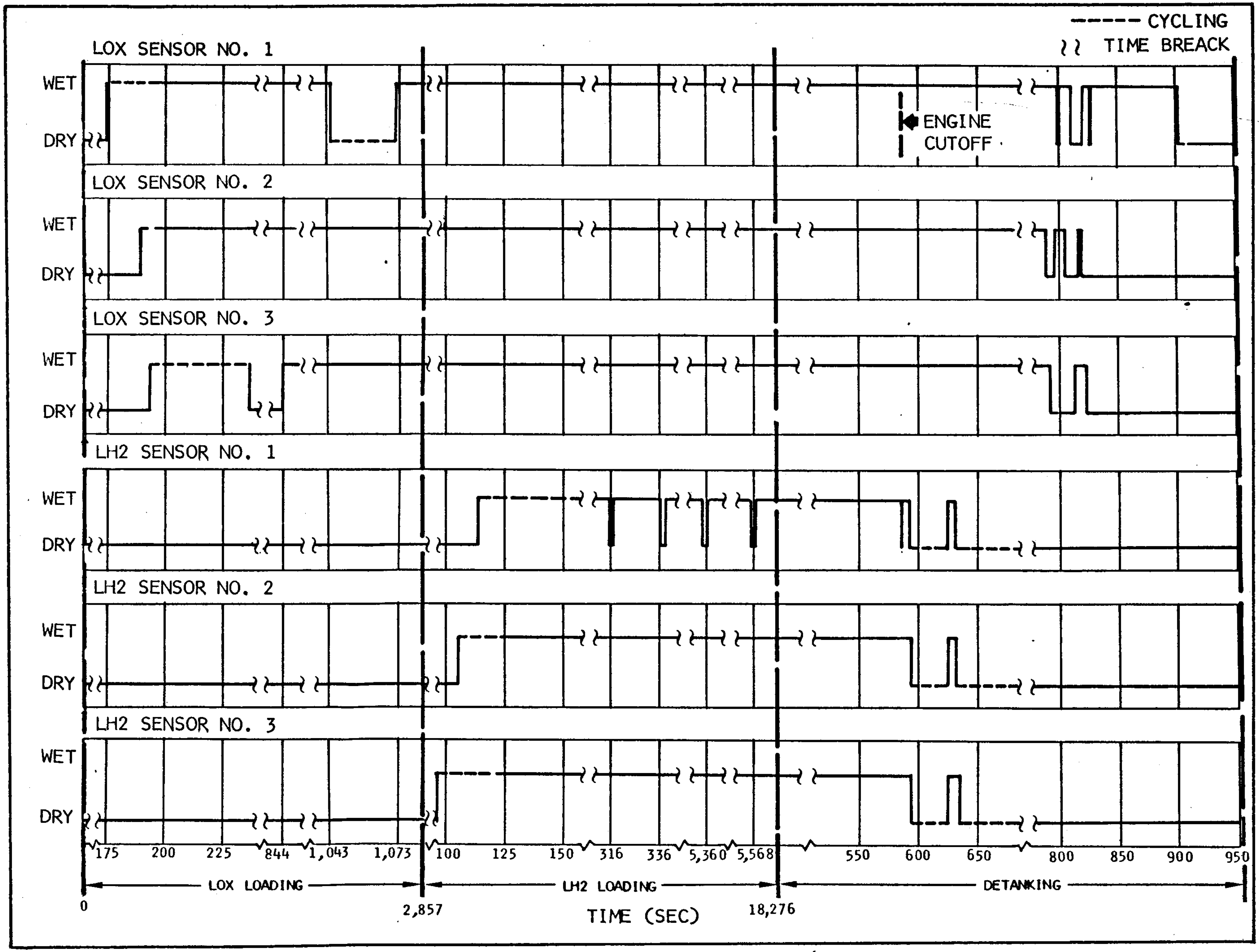


Figure 12-1. Depletion Level Sensor History

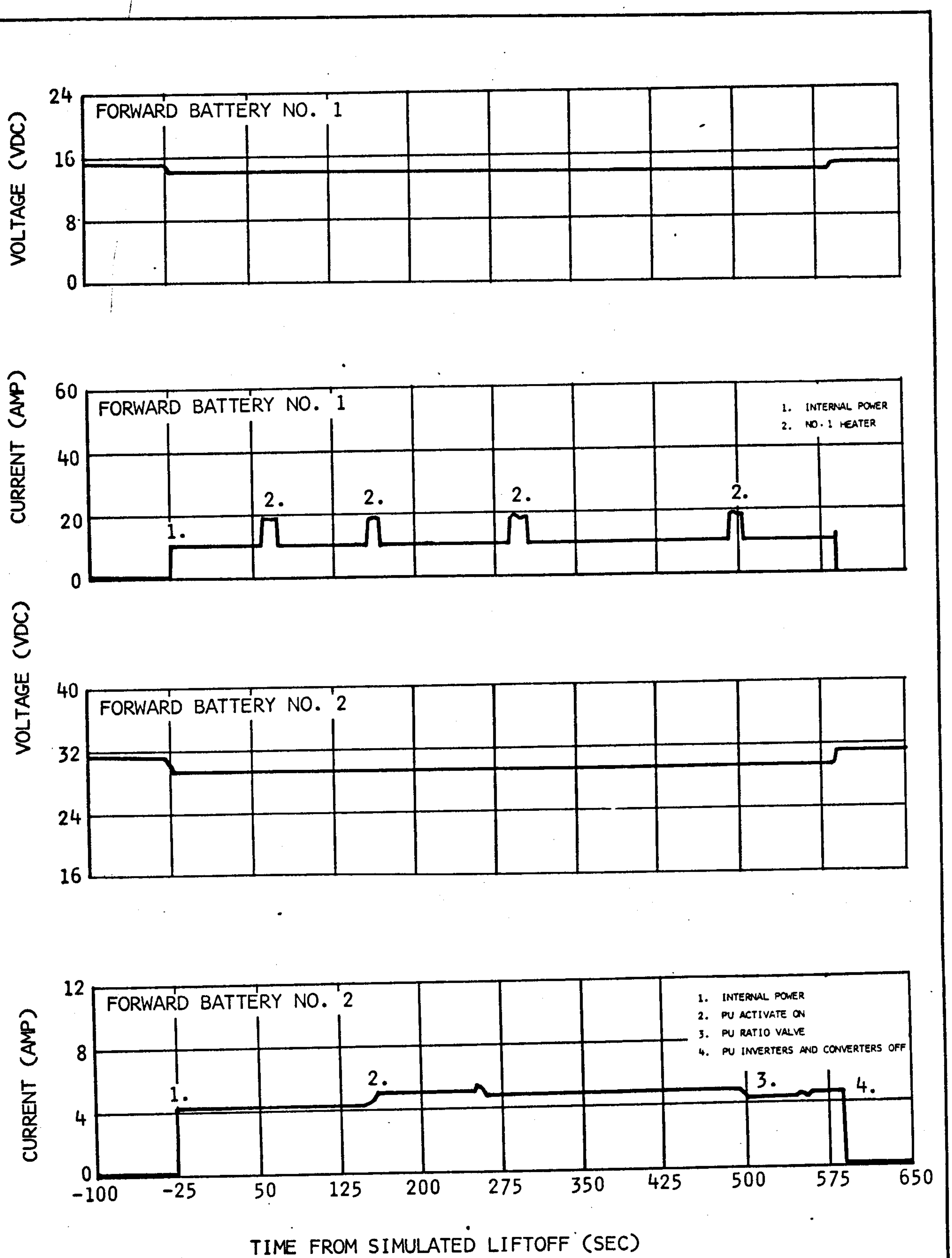


Figure 12-2. Forward Battery Voltage and Current Profiles

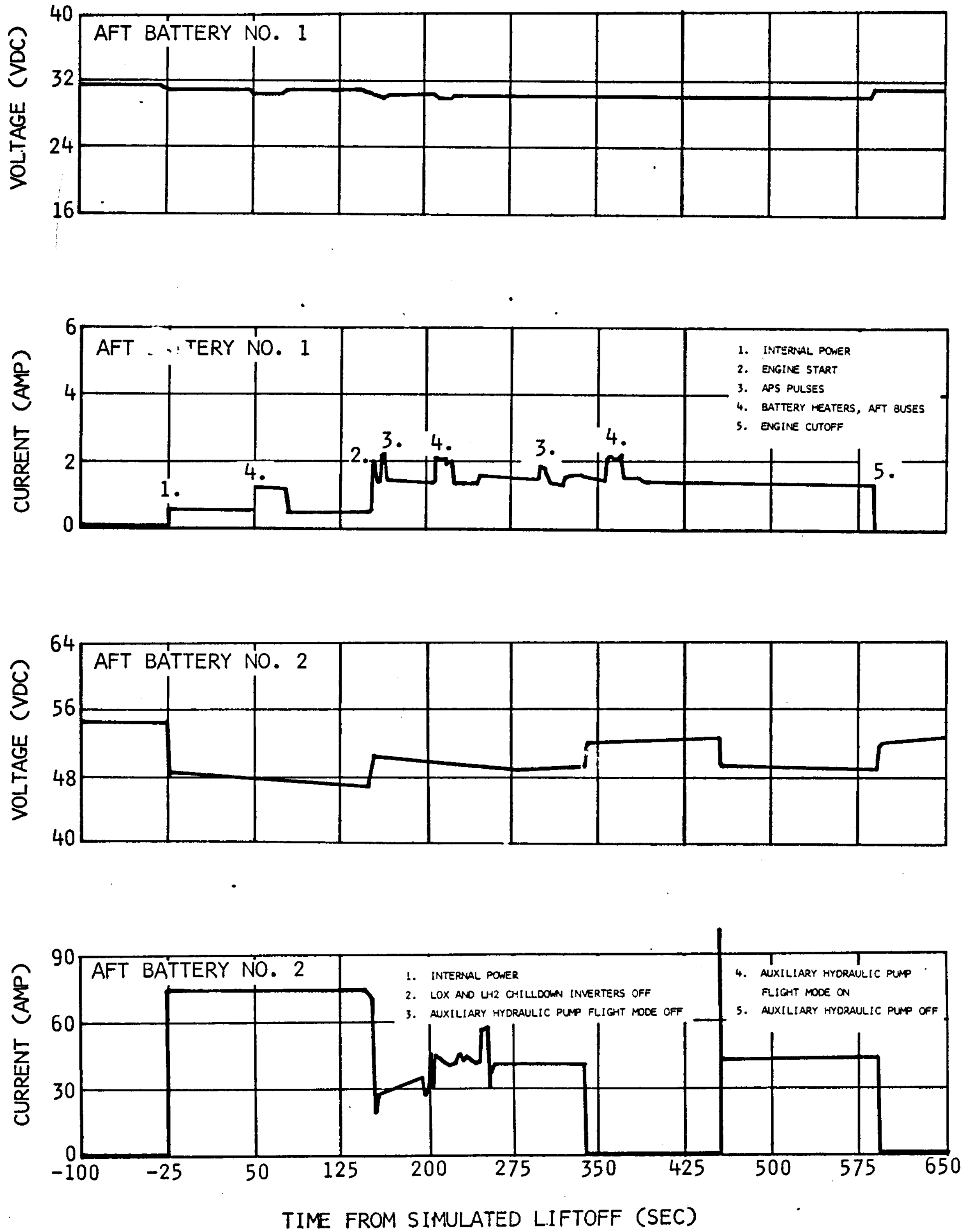


Figure 12-3. Aft Battery Voltage and Current Profiles

13. HYDRAULIC SYSTEM

13.1 Hydraulic System Operation

The hydraulic system test program was completed successfully during countdown 614070, a single firing of 436 sec duration. System running time from auxiliary pump ON, prior to simulated liftoff, to auxiliary pump OFF following cutoff was 1,717.5 sec. The gimbal program was initiated after the engine start transient side loads subsided and the engine support links dropped. The auxiliary pump was turned OFF for a period after the gimbal program to verify engine-driven pump operation. Test plan objectives were satisfied and all system variables were within design limits.

Significant event times are presented in the following table:

EVENT	TIME (Sec)
Auxiliary Pump ON	T_o -608.4
Simulated Liftoff	(T_o +0)
Engine Start/Engine-driven Pump START	T_o +150.8
Engine Support Links DROPPED	T_o +185.5
Gimbal Program START	T_o +198.7
Gimbal Program Complete	T_o +255.0
Auxiliary Pump OFF	T_o +335.9
Auxiliary Pump ON	T_o +451.9
Engine Cutoff/Engine-driven Pump STOP	T_o +586.9
Auxiliary Pump OFF	T_o +1,109.1

13.2 System Pressure at Salient Times

The GN2 precharge, corrected to 70 deg F, was recorded as 2,245 psia prior to the firing and 2,305 psia after the firing. While the inference is that the precharge may have been 50 psi low, the GN2 gage on the fill chart indicated an acceptable precharge (2,350 $\pm$50 psig) prior to the firing; the gage reading was greater than telemetered data by approximately 50 psi.

Hardware system pressure data exceeded telemetered system pressure data by 35 psi, so it is assumed the GN2 data (telemetered) was on the low side of the allowable instrumentation accuracy (approximately ± 2 percent). Return pressure prior to the firing (a bootstrap function of the GN2 precharge) was 79 psia, which can be used to infer that GN2 precharge: (79 psia -27 psia vent cavity pressure +10 psi seal friction x 37.2 bootstrap ratio) was 2,350 psig, corrected to 70 deg F, which is what the gage read. In any case, there was no GN2 leakage detected and the accumulator functioned normally.

The auxiliary pump compensator and engine-driven pump compensator were very similar in output pressure at 3,625 psia. At engine ignition, an increase to 3,635 psia was observed, but it quickly subsided to 3,625 psia. Auxiliary pump motor amperage data indicated the auxiliary pump was carrying the system leakage flow, but the compensator settings were so close no change was detected during the auxiliary pump OFF period (T_o +335.9 to T_o +451.9 sec).

GN2 pressure data duplicated all trends in the system pressure data, and although lower, were within data acquisition accuracy. The accumulator piston did not bottom in the oil-filled direction.

Significant pressures are presented in the following table:

TIME (Sec)	SYSTEM PRESSURE (psia)	RESERVOIR PRESSURE (psia)
T_o -608.4	3,625	181
T_o +150.8	3,635	181
T_o +198.7 to 255.0	3,675 max 3,550 min	193 max 162 min
T_o +1,109.1	3,625	181

13.3 Reservoir Level at Salient Times

Reservoir level prior to system operation was 93.9 percent at an approximate average system temperature of 66 deg F, equivalent to 94.5 percent at 70 deg F. Minimum level during operation was 34.3 percent and the maximum, prior to auxiliary pump OFF at T_o +1,109.1, was 39.2 percent.

13.4 Hydraulic Fluid Temperature History

TIME (Sec)	ENGINE-DRIVEN PUMP INLET (°F)	RESERVOIR (°F)	ACCUMULATOR GN2 (°F)
T_o -608.4	84/97	66	60/68
T_o +150.8	114	95	68
T_o +198.7 to 255.0	110 min 119 max	93 to 99	Steady Increase
T_o +335.9	121 to 129	99	Steady Increase
T_o +451.9	136 to 126	103	Steady Increase
T_o +586.9	130	107	Steady Increase
T_o +1,109.1	133	122	70

13.5 Engine Side Loads

Peak loads in the support links and actuators during engine start transients are presented in the following table (corrected for prestart bias):

ITEM	LOAD (lbf)
Pitch Link	+23,000 -15,000
Yaw Link	+18,000 -23,000
Pitch Actuator	+1,178 -12,960
Yaw Actuator	+5,300 -10,000

13.6 Hydraulic Fluid Flowrates

Calculated from reservoir fill and emptying rate during system operation:

ITEM	FLOW (GPM)	ALLOWABLE (GPM)
System Internal Leakage	0.59	0.40 to 0.80
Auxiliary Pump Flowrate	1.72	1.50 min

13.7 Auxiliary Pump Power Requirements

FLOW (GPM)	CURRENT (AMP)	VOLTAGE (VDC)
0.59	43.7	57
1.72	75	57

13.8 Miscellaneous

Using actuator differential pressure readings from data immediately prior to and following engine cutoff, the thrust offset (using 164K net thrust) was 0.026 in. from the stage longitudinal axis, located 16 deg from fin plane II toward fin plane III.

14. FLIGHT CONTROL SYSTEM

The dynamic response of the hydraulic-servo thrust vector control system was measured while the J-2 engine was gimbaled during the acceptance firing of the S-IVB-206 stage. The performance of the pitch and yaw hydraulic servo control systems was found to be acceptable.

14.1 Actuator Dynamics

The actuator frequency response of the pitch and yaw hydraulic servo system for a ±1/2 deg sinusoidal signal between 0.6 and 9 cps, and for a ±1/4 deg sinusoidal signal between 0.6 and 2 cps is plotted in figures 14-1 and 14-2. The acceptable limits are shown and as noted, the phase and gain response data fall within these limits.

Phase lag between actuator-piston position and command current at 1 cps is presented in the following table:

SINUSOIDAL COMMAND (DEG)	COMMAND FREQUENCY (CPS)	PHASE LAG (DEG)
$\pm\frac{1}{4}$ - pitch	0.88	-34
$\pm\frac{1}{2}$ - pitch	0.89	-33
$\pm\frac{1}{4}$ - yaw	0.98	-35
$\pm\frac{1}{2}$ - yaw	0.97	-30

14.2 Engine Slew Rate

A nominal two-deg step command was applied to the pitch and yaw actuators from which the engine slew rates were determined. The minimum acceptable slew rate is 8 deg/sec. A nominal slew rate for a two-deg step without the effects of gimbal friction being felt is 13.6 deg/sec.

The measured values were found to be acceptable and are shown in the following table.

ACTUATOR	CONDITION	ENGINE TRAVEL (DEG)	ACTUATOR RATE DEG/SEC
Pitch	Retract	0.0 to +2.0	11.9
	Extend	+2.0 to 0.0	11.9
	Extend	0.0 to -2.0	12.4
	Retract	-2.0 to 0.0	11.8
Yaw	Extend	0.0 to +2.0	12.7
	Retract	+2.0 to 0.0	13.0
	Retract	0.0 to -2.0	11.5
	Extend	-2.0 to 0.0	11.2

The minimum engine slew rate was 11.2 deg/sec which corresponds to an actuator piston rate of 2.32 in./sec when using a conversion of 4.83 deg of engine rotation per in. of actuator movement. Thus, in all cases, the actuator exceeded the minimum acceptable rate of 1.66 in./sec, or 8 deg/sec of travel.

14.3 Differential Pressure Feedback Network

The differential pressure feedback network in the pitch and yaw hydraulic servo valves was operating properly since adequate system damping was demonstrated by observing the actuator differential pressure measurements during the two-deg step response tests. The differential pressures decreased in amplitude as a function of time without appearing to "ring "(figure 14-3).

14.4 Cross-Axis Coupling

A minimum amount of cross-axis coupling occurred as seen by the generated actuator differential pressure in the non-gimbaled plane.

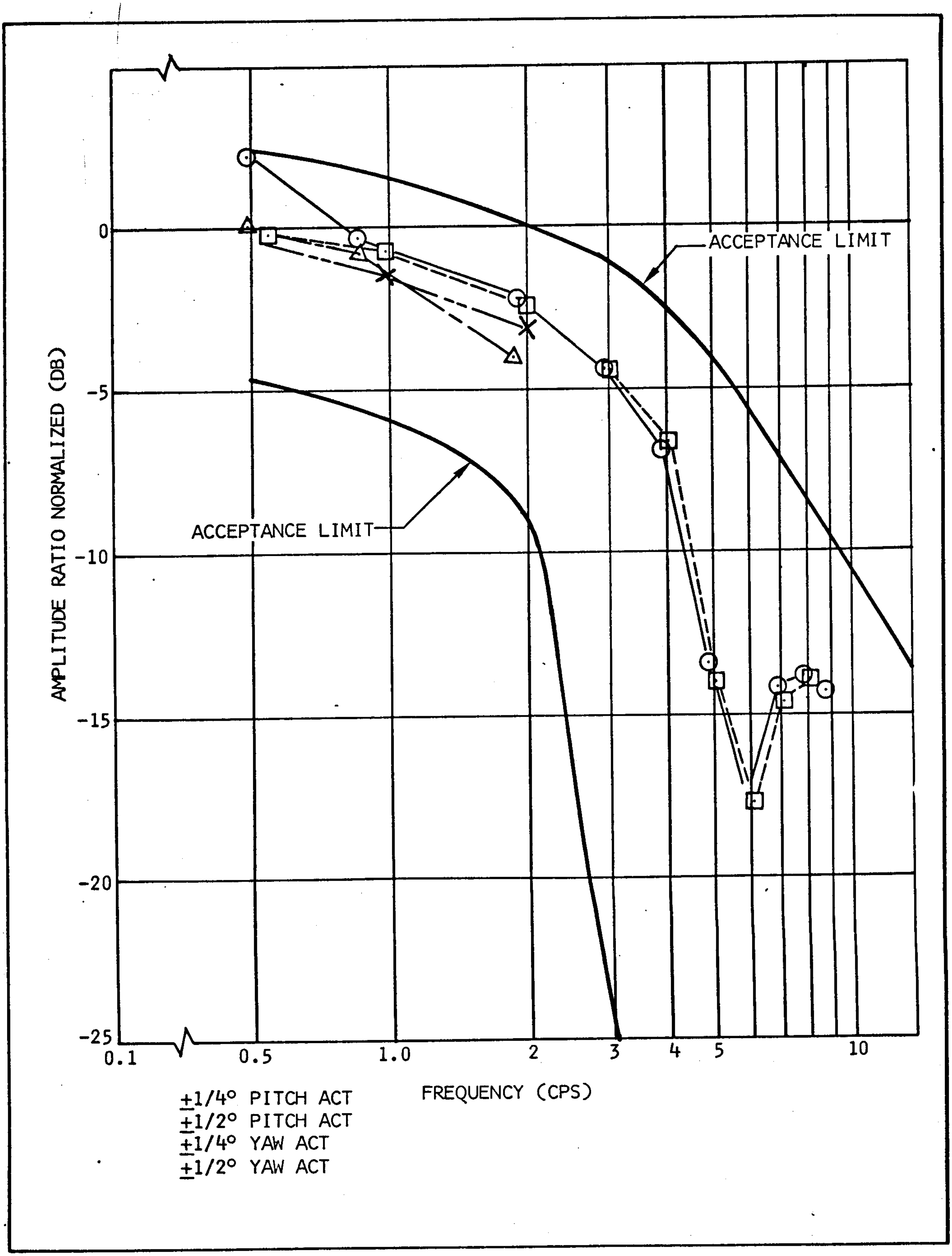


Figure 14-1. Actuator Response (Gain)

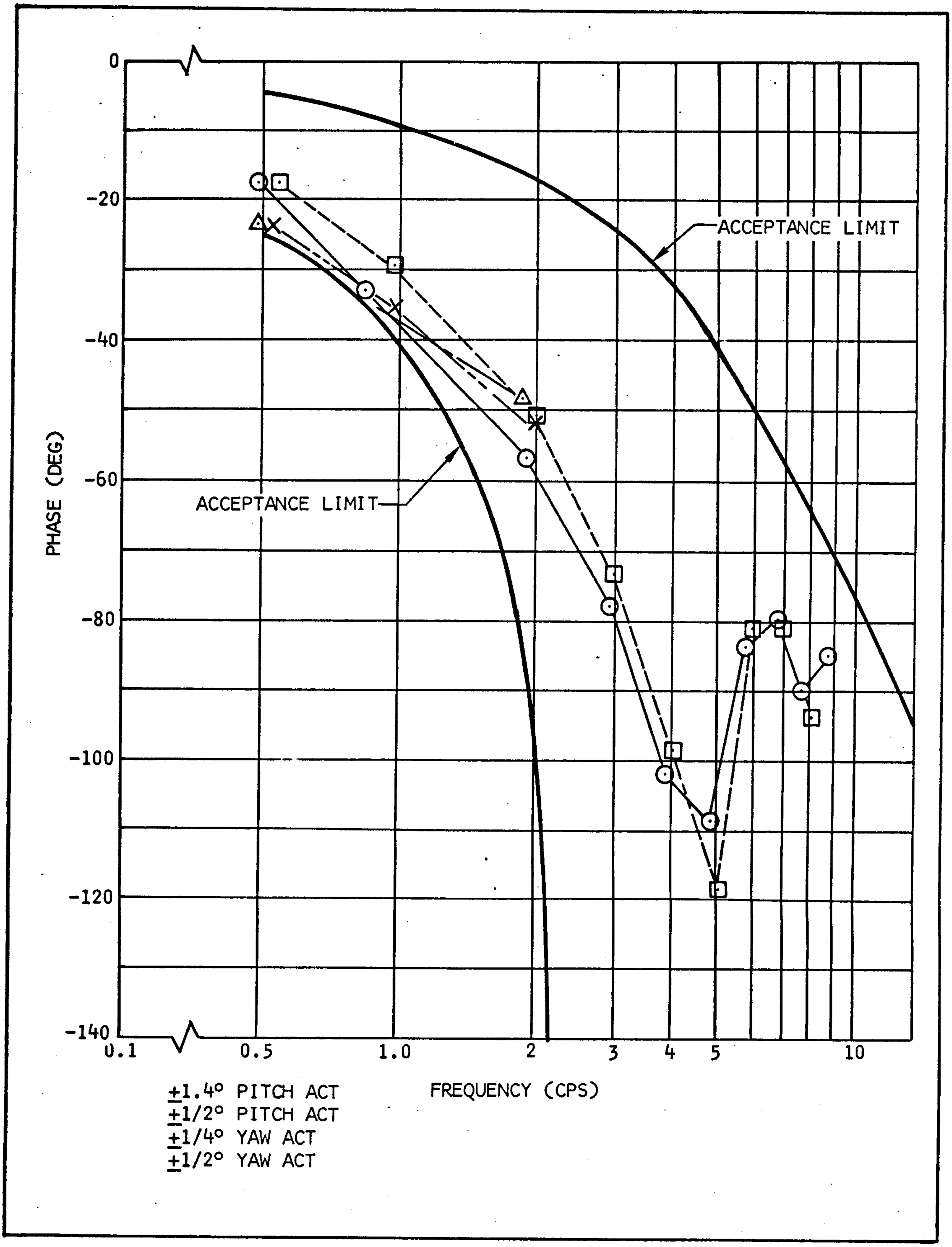


Figure 14-2. Actuator Response (Phase Lag)

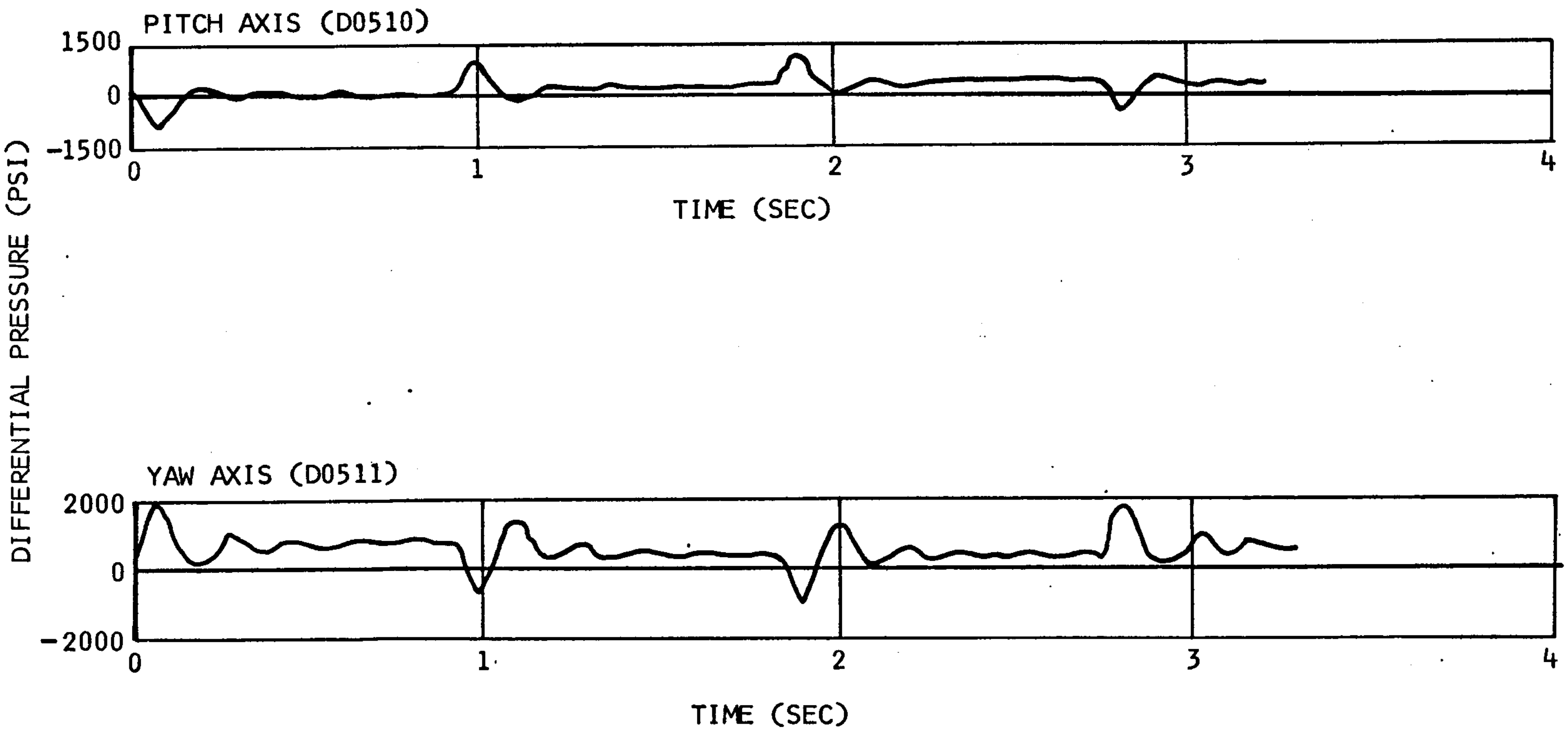


Figure 14-3. Actuator Differential Pressure (± 2 deg Transient Response)

15. STRUCTURAL SYSTEMS

Structural integrity of the S-IVB-206 stage was maintained for the vibration, temperature, and thrust load conditions of the acceptance firing and the engine performance verification firing. Minor structural debonding of supports in the tunnels occurred, but these installations have been repaired. A number of small voids under the LH2 tank fiberglas cloth liner were detected after the firings, but these voids have been filled with resin. The aft skirt purge manifold fabric seal which partially debonded from the LOX tank dome, apparently due to a pressure pulse at engine ignition, has been rebonded; whereas, all subsequent S-IVB stages to be acceptance fired will be provided with a newly designed, improved fabric seal.

15.1 Common Bulkhead

A post acceptance firing visual inspection of the common bulkhead disclosed no ripples or other abnormalities on the forward face. A growler check of the bulkhead's forward dome indicated no core-to-dome separation. A dye check of the forward dome weld seams revealed no cracks, porosity or other defects. These results, combined with satisfactory common bulkhead pressure decay checks and gas sample surveys, indicate the dome portion of the bulkhead is sound. The results of the pressure checks and gas surveys are presented in Douglas Report No. SM-37540, S-IVB-206 Stage Acceptance Firing 15 Day Report, dated October 1966.

15.2 LH2 Tank Interior

Visual inspection of the LH2 tank liner revealed seven voids up to ten sq in. in area under the fiberglas cloth liner. These voids were not considered detrimental to thermal insulation or to structural integrity; however, to insure against further delamination, the voids were filled by injecting resin through the liner using a hollow needle. The injection holes in the liner were sealed with resin.

The tank interior inspection also disclosed one crack, seven inches long, in the fiberglas on the forward dome and several hairline cracks in the LH2 tank cylindrical liner. The cracks were sealed by bonding-on fiberglas cloth strips and coating with resin.

Between firings, an ultrasonic inspection was performed on limited areas of the LH2 tank cylindrical wall. This inspection was performed to verify that ice formation on the tank had not been caused by tank insulation debonding. The results of this inspection indicated that no insulation debonding had occurred.

The visual inspection of the LH2 tank interior also revealed miscellaneous foreign material in the "V" block area at the common bulkhead joint. This material included small polyurethane shavings from the insulation and several small metal parts such as washers and rings believed to be from the access kit. Also a small amount of corrosive or heat discoloration was detected on the stainless steel weld seams of the anti-vortex screen assembly. The foreign material and the weld discoloration have been thoroughly removed.

15.3 Exterior Structure

A visual exterior inspection of the stage thrust structure, LOX tank aft dome, aft skirt, LH2 tank cylindrical section, LH2 tank forward dome, and forward skirt revealed no structural damage after the full duration firing and the 67-sec engine performance verification firing with the exception of minor debonding of supports. Two completely debonded nylon supports were found in the main tunnel during post-acceptance firing inspection. Post-engine verification inspection revealed one completely debonded nylon support in the main tunnel, one partially debonded aluminum finger type support in the main tunnel, and one partially debonded aluminum strap in the auxiliary tunnel. The partially debonded supports were removed and all affected supports were rebonded using silane primer for preparing the metal surfaces.

15.4 Aft Purge Manifold Seal

The fabric seal of the aft skirt purge manifold debonded at numerous places from the LOX tank aft dome apparently at the two times of J-2 engine ignition. (The seal was rebonded between firings). This debonding appears to have been caused by an overpressure pulse at the seal caused by the J-2 engine ignition. Prior to this time, for both firings, the purge manifold had functioned properly to provide thermoconditioning and purging. Following J-2 engine ignition, the purge manifold is not used in flight; hence, damage to the seal at the time of ignition is of no significance to flight tests;

however, for acceptance firing, damage to the manifold seal bonding at the time of J-2 engine ignition results in a redistribution in the continued purge flow through the skirt, APS modules, and thrust structure. This redistribution of purge flow has been determined to be of negligible significance. The equipment and electronics within the aft skirt are protected by the flame impingement curtain at the bottom of the skirt independently of the condition of the manifold seal bonding.

A redesign has been made of the purge manifold which will take into account the high pressure wave which apparently debonds the fabric seal. This change will provide a new, improved fabric seal between frames at stations 240 and 256, thus making the seal independent of the LOX tank dome. This redesign is being phased in on the S-IVB-207 stage and on the S-IVB-503 stage.

On the S-IVB-206 stage, the fabric seal of the aft skirt manifold has been rebonded to the LOX tank dome.

16. THERMOCONDITIONING AND PURGE SYSTEMS

16.1 Aft Skirt Thermoconditioning and Purge System

The aft skirt GN2 purge was initiated prior to LOX loading and maintained throughout the acceptance firing until completion of final tank purges.

16.1.1 Aft Skirt GN2 Flowrate

The GN2 flowrate was maintained between 3,400 and 3,500 SCFM throughout the acceptance firing.

16.1.2 Aft Skirt GN2 Temperatures

The aft skirt umbilical inlet temperature (C0700) cycled between 104 and 109 deg F throughout the firing. GN2 temperature at the APS module thermoconditioning system outlet sensors (C0663) was constant at 90 deg F.

16.1.3 Aft Skirt Umbilical Inlet Pressure

The umbilical inlet pressure (D0767) cycled between 13.3 and 14.1 in. H_2O throughout the firing.

16.1.4 Non-Flight Hardware

a. APS Modules:

The flight modules were replaced with two Model DSV-4B-188B APS Simulators. These replacements functionally represent the flight module thermoconditioning system.

b. Aft Interstage:

The Model DSV-4B-540 dummy interstage was used to support the stage on the test stand. Use of the dummy interstage lowers the aft skirt purge system internal pressures very slightly, but does not materially affect the overall system purge capabilities.

16.2 Forward Skirt Environmental Control and Thermoconditioning System

The forward skirt GN2 purge was initiated prior to LOX loading and maintained throughout the firing until completion of final tank purges. The Model DSV-4B-359 Thermoconditioning System Servicer circulated thermally conditioned fluid through the thermoconditioning system throughout the firing.

16.2.1 Forward Skirt GN2 Flowrate

The GN2 flowrate was maintained at design conditions of 500-600 SCFM throughout the firing.

16.2.2 Forward Skirt GN2 Temperature

The forward skirt GN2 internal temperature (C0768) remained between 52 and 55 deg F throughout the firing.

16.2.3 Forward Skirt Internal Pressure

The forward skirt internal pressure (D0868) held constant at 0.83 in. H_2O. throughout the firing. The forward skirt relief valve setting is 2.0 in. H_2O.

16.2.4 Forward Skirt Thermoconditioning System Temperature

The thermoconditioning system fluid inlet temperature (C0753) cycled in a normal manner between 56 and 62 deg F.

16.2.5 Non-Flight Hardware

Model DSV-4B-359 Thermoconditioning System Servicer: The servicer supplies thermally conditioned fluid to the forward skirt cold plates during all field station operations requiring power to the forward skirt electronic equipment. When staged, the cold plates will receive fluid from the NASA instrument unit thermoconditioning system.

17. ACOUSTIC AND VIBRATION ENVIRONMENT

A total of fourteen vibration measurements were monitored during the acceptance firing and/or the engine performance verification firing. Eleven measurements provided usable data, one did not provide data, and the data from two measurements were considered usable only for trend purposes. There were no acoustic measurements monitored.

There was no evidence of any vibration problems during either firing. There was an anomaly in the data from the LOX feedline measurements during the acceptance firing. Although the cause of the anomaly was not determined, the instrumentation systems were modified and valid data were obtained during the engine performance verification firing.

17.1 Data Acquisition

All measurements were monitored via the hardwire link, and were FM recorded. The frequency responses of the recording systems used were from 5 to 500 cps and from 5 to above 3,000 cps. A list of the measurements is presented in table 17-1 and the accelerometer locations are shown in figure 17-1. Included in the table are composite levels measured during start transient and mainstage of both firings.

A major problem was encountered with the LOX feedline measurements during the acceptance firing which invalidated six of the measurements. The problem appeared to be connected with the instrumentation system; therefore, to alleviate repeating the same problem during the engine verification firing, a different instrumentation system was installed resulting in only two measurement failures. The specific reasons for the invalid data during the acceptance firing have not been determined.

17.2 Vibration Measurements

The vibration measurements were limited to the engine and LOX feedline.

The four engine measurements included one at the LOX turbopump, one at the LH2 turbopump, and two on the combustion chamber dome. The data from these measurements are shown in figure 17-2. The data from the LOX and LH2 turbopump measurements exhibited the same spectrum shape as those from past acceptance firings; however, the overall amplitudes were 10 to 20 db lower, indicating a possible error in calibration. These data should be used only for trend purposes. The vibration levels on the combustion chamber dome were in good agreement with those from past acceptance firings.

The data from the engine measurements did not indicate any trend that could be correlated to the problem with the LOX turbopump degradation during the acceptance firing.

Ten measurements were located on the LOX feedline in locations similar to those monitored during formal qualification tests to determine the vibration input and response of the duct (figure 17-3). The data from these measurements verified the adequacy of the vibration test levels and test setup in the formal qualification tests of the LOX feedline.

TABLE 17-1
COMPOSITE VIBRATION LEVELS

MEASUREMENT NO.	PARAMETER	DIRECTION	FREQUENCY RANGE (CPS)	ACCEPTANCE FIRING		ENGINE VERIFICATION	
				START TRANSIENT (Grms)	MAINSTAGE (Grms)	START TRANSIENT (Grms)	MAINSTAGE (Grms)
E0613-424	LOX Feedline, Center	Parallel	5 to 500	I	I	4.5	4.9
E0614-424	LOX Feedline, Center	Normal	5 to 500	I	I	4.4	4.4
E0615-424	LOX Feedline, Center	Tangential	5 to 500	I	I	2.8	3.4
E0616-424	LOX Feedline at Tank	Thrust	5 to 500	I	I	2.1	2.6
E0617-424	LOX Feedline at Engine	Thrust	5 to 500	I	I	3.1	3.1
E0619-424	LOX Feedline, F.Q. Pos 3	Tangential	5 to 3,000	I	I	I	I
E0620-424	LOX Feedline, F.Q. Pos 3	Normal	5 to 500	4.8	3.2	I	I
E0621-424	LOX Feedline at Engine	Tangential	5 to 500	N/M	N/M	1.1	1.6
E0622-424	LOX Feedline at Tank	Normal	5 to 500	N/M	N/M	0.5	0.7
E0623-424	LOX Feedline, F.Q. Pos 3	Parallel	5 to 3,000	N/M	N/M	10.2	9.8
E0555-401	LOX Turbopump	Lateral	20 to 3,000	T	T	T	T
E0556-401	LH2 Turbopump	Lateral	20 to 3,000	T	T	T	T
E0706-B03	Safety Cutoff No. 2	Thrust	20 to 3,000	6.1	5.5	7.6	5.7
E0707-B03	Safety Cutoff No. 1	Thrust	20 to 3,000	6.9	7.1	6.4	7.1

I = Invalid Data
N/M = Not Monitored
T = Trend Data

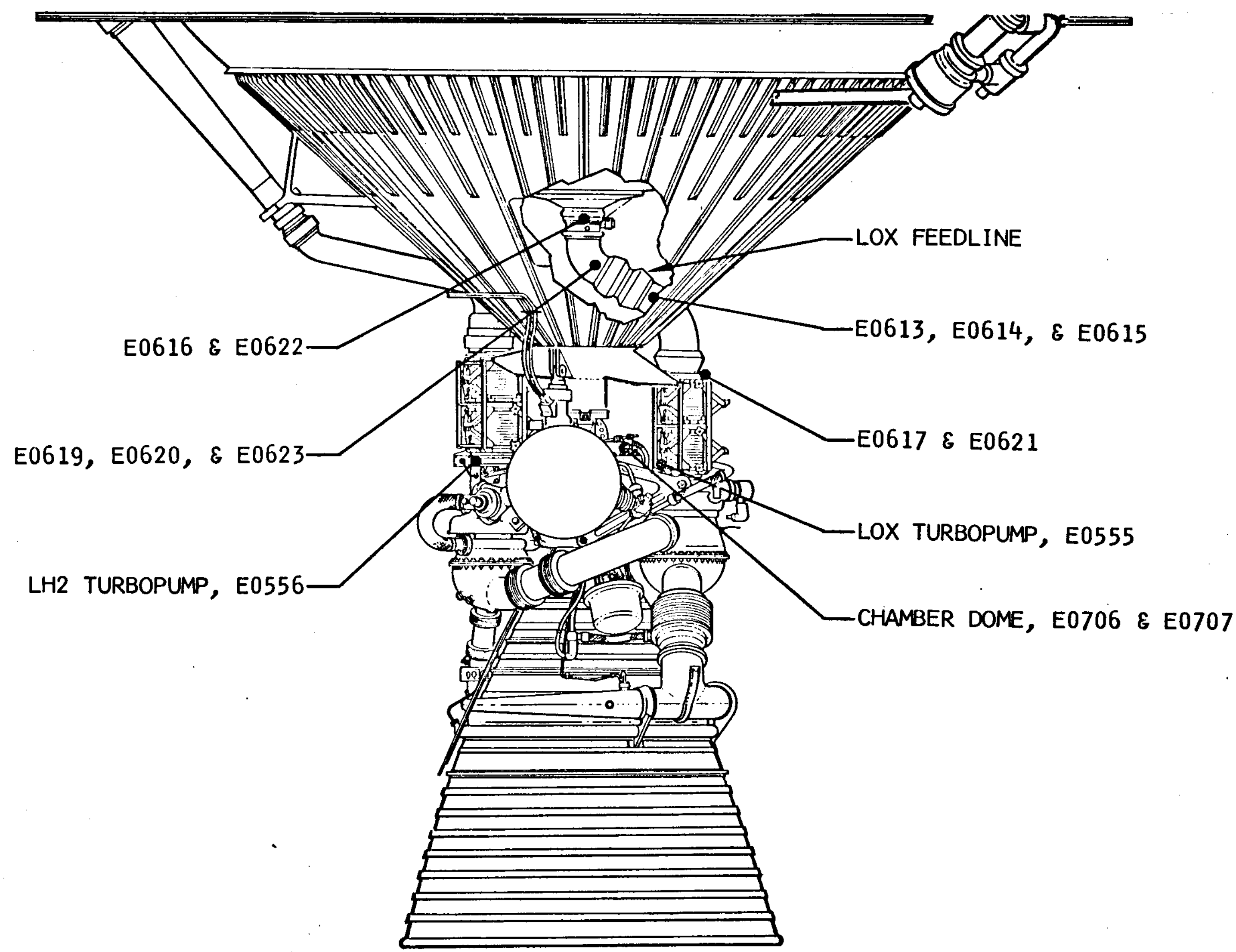


Figure 17-1. Vibration Measurement Locations

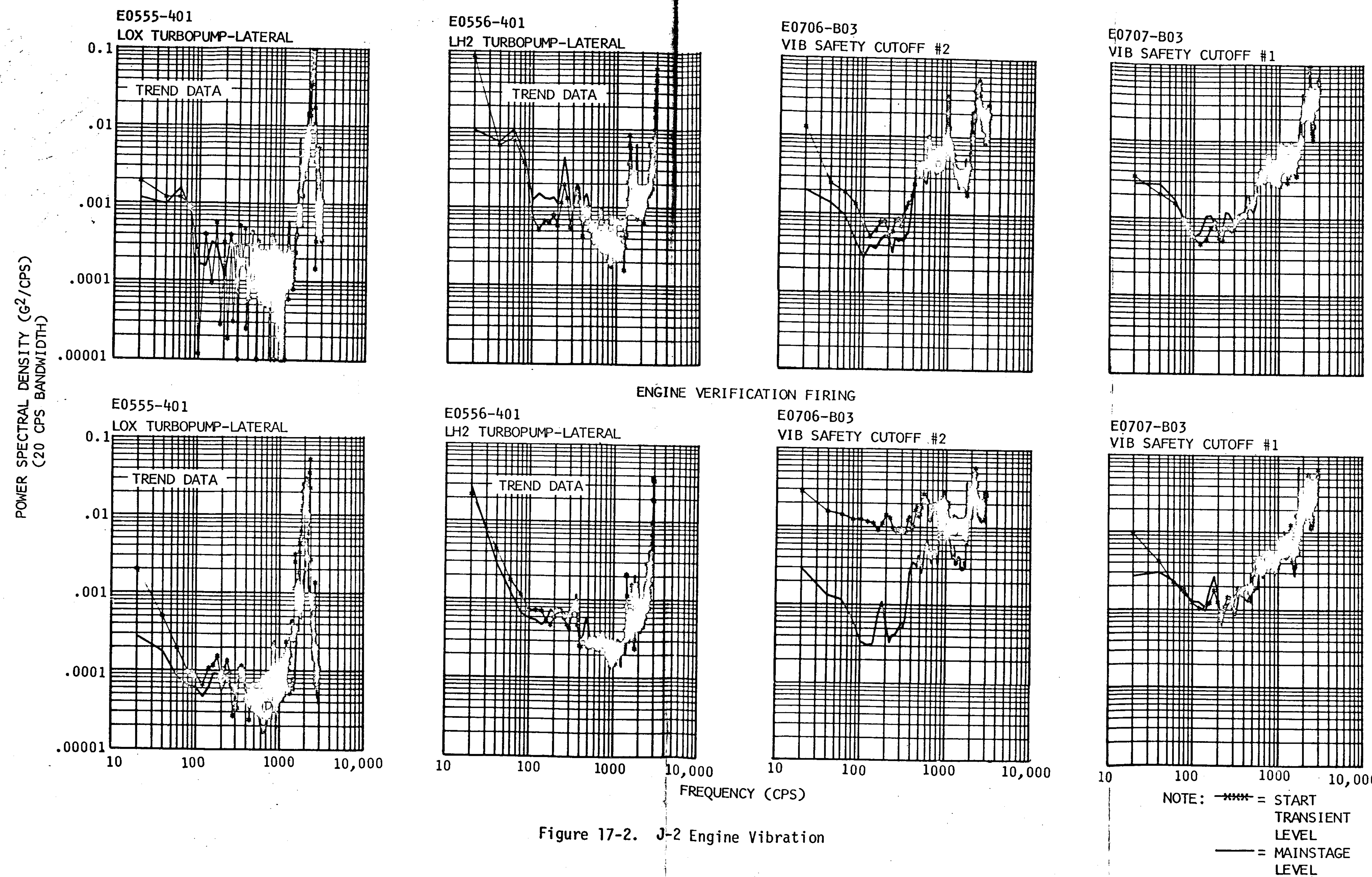


Figure 17-2. J-2 Engine Vibration

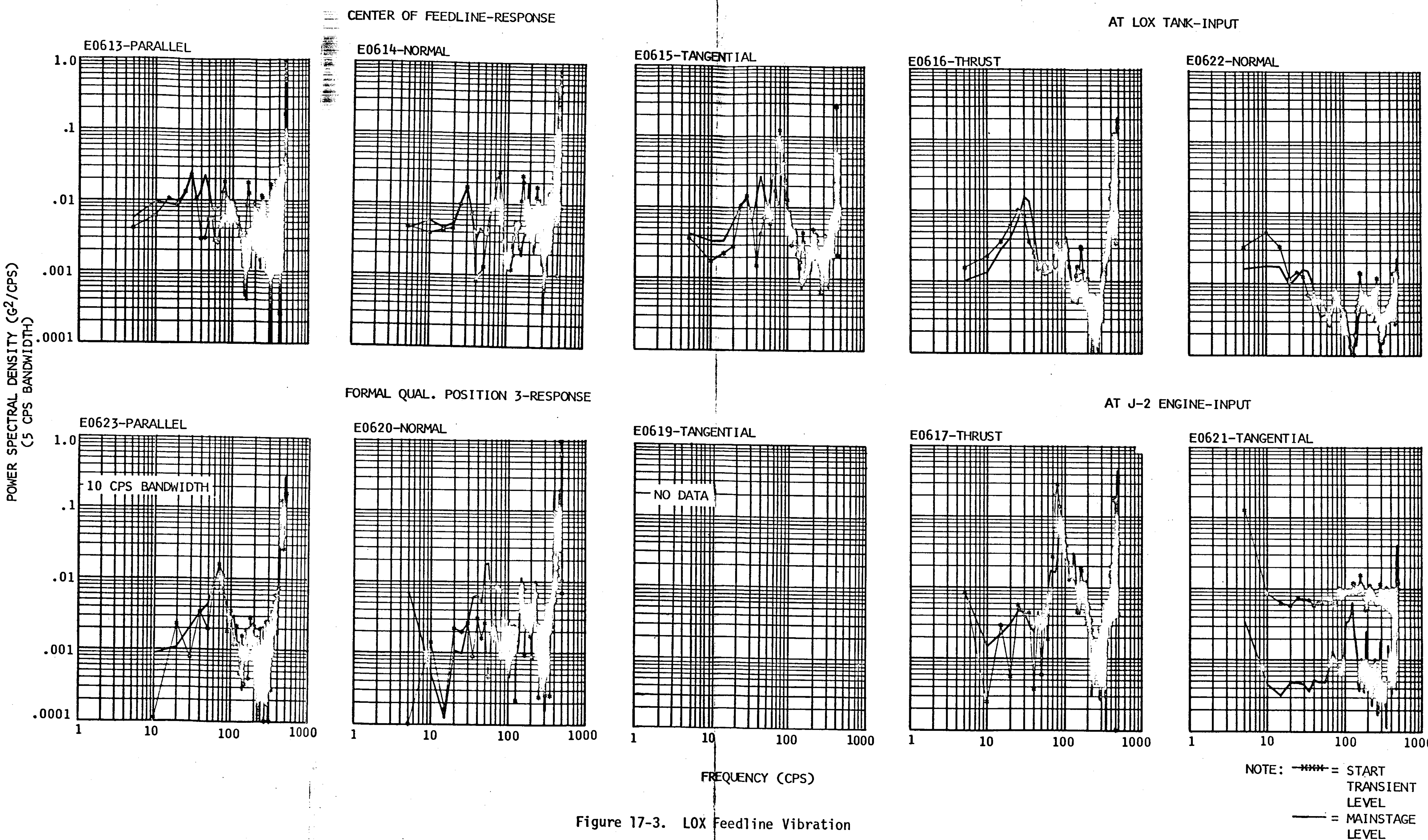


Figure 17-3. LOX Feedline Vibration

18. RELIABILITY AND HUMAN ENGINEERING

18.1 Reliability Engineering

All functional failures of Flight Critical Items (FCI) and Ground Support Equipment/Special Attention Items (GSE/SAI) were investigated by Reliability Engineering. Significant malfunctions of Flight Critical Items documented are noted in table 18-1.

18.2 Human Engineering

A Human Engineering evaluation of the S-IVB-206 stage acceptance firing was performed. During the test stand inspection, following propellant loading, personnel were required to re-torque one of the valves on the LH2 valve complex. It was discovered that a spark-resistant torque wrench was not available to perform this task safely; however, a standard spark-resistant wrench was used. It has been recommended that a spark-resistant torque wrench be included with the tools available prior to countdown initiation.

During this acceptance firing, the Vehicle Monitor Panel meter overlays were employed (successfully) as recommended in HER A45-058. Saturn Propulsion requested that Human Engineering provide meter overlays for each acceptance firing. A fabrication order is in preparation authorizing the development of aluminum overlays with silk-screened scale values for all-weather conditions on the test stands. These overlays provide meter scale values in psia so that they can be read accurately (without the requirement for conversion) on the television monitor in the Test Control Center (TCC).

A Human Engineering evaluation was performed of the refiring of S-IVB-206 stage on 14 September 1966. It was observed that personnel at the Sony video tape recorder positions did not have a countdown clock in their field of vision in the TCC. HER A45-059 recommends that an additional countdown clock be installed in the instrumentation area of the Complex Beta TCC within the normal field of vision of the Sony and oscillograph recorder positions.

TABLE 18-1 (Sheet 1 of 4)
FLIGHT CRITICAL COMPONENTS MALFUNCTIONS

P/N AND S/N	PART	TROUBLE	CAUSE	ACTION TAKEN
1A66241-503 S/N 454594	Pump, Hydraulic, Aux Motor Driven	During pre-test hydraulic set-up and operation procedure per 1B41005, the pressure was 3,300 psig as monitored on the control center strip chart. Minimum operating pressure is 3,550 psig. Per A3 design instructions, the pressure was adjusted via the pump pressure compensator to 3,600 psig. Subsequent pressure checks revealed no change in pressure.	Undetermined. Possible cocked spring in the pressure compensator.	The pump was acceptable to engineering for use and will remain on the stage. No further action contemplated.
1A49982-517 S/N 020	Module, Actuation Control	During propulsion system leak checks per 1B70176, the module was leaking 130 scim through the vent port with the boost close pilot valve in the closed position. Leakage increased from 0-130 scim in approximately 45 secs after the pilot solenoid was energized. Maximum allowable leakage is 1.2 scim.	Inadequate design.	A newly designed module (P/N 1B65292-501) will replace this part beginning with S-IVB-205 and subs. and S-IVB-501 and subs. The faulty module was replaced with S/N 128 and shipped to A-MRCC before being routed to the vendor.

TABLE 18-1 (Sheet 2 of 4)
FLIGHT CRITICAL COMPONENTS MALFUNCTIONS

P/N AND S/N	PART	TROUBLE	CAUSE	ACTION TAKEN
1A49982-517 S/N 009	Module, Actuation Control	During propulsion system leak checks per 1B70176, the module failed to provide pneumatics to the fill and drain valve. The electrical connector was removed from the module open solenoid and voltage readings were taken looking back into the control center; proper source voltage was verified. The solenoid was energized and the valve failed to open. The solenoid became warm, indicating the solenoid was drawing current.	Undetermined.	Module replaced with a like item, (S/N 173) and shipped to A-MRCC for further evaluation.
1A49982-517 S/N 173	Module, Actuation Control	During propulsion system leak checks per 1B70176, the module was leaking 10,000 scim through the vent port with the open pilot valve in the open position. Maximum allowable leakage is 1.2 scim.	Inadequate design.	A newly designed module (P/N 1B65295-501) will replace this part beginning with S-IVB-205 and subs, and S-IVB-501 and subs. The faulty module was replaced with S/N 126 and shipped to A-MRCC before being routed to the vendor.

TABLE 18-1 (Sheet 3 of 4)
FLIGHT CRITICAL COMPONENTS MALFUNCTIONS

P/N AND S/N	PART	TROUBLE	CAUSE	ACTION TAKEN
1A74039-509 S/N 0006	Inverter Electronic Assembly -Childown	During debugging of the acceptance firing tape, the inverter failed to operate when programmed. Turn-on was executed by the computer. A review of aft bus No. 2 voltage and current monitor strip chart revealed that there was no current increase at the time the inverter was turned on; however, earlier in the day the inverter had been turned on and several current spikes with magnitudes ranging between 250 to 270 amp occurred.	To be determined.	Inverter replaced with a like item (S/N 005) and shipped to A-MRCC for failure analysis.
103826 S/N 2046	J2 Engine	During turbine inspection following the full duration acceptance firing per CD614070, small metal particles were found in the LOX pump turbine manifold. A more detailed inspection following removal of the first and second stage rotors and the stator assembly revealed considerable rubbing between the first stage rotor and stator.	To be determined by Rocketdyne.	The LOX pump (P/N 458175-71, S/N 6634950) was replaced by a later pump configuration, P/N 458175-81 which incorporates thicker turbine wheels. This is a GFE item.

TABLE 18-1 (Sheet 4 of 4)
FLIGHT CRITICAL COMPONENTS MALFUNCTIONS

P/N AND S/N	PART	TROUBLE	CAUSE	ACTION TAKEN
103826 S/N 2046	J2 Engine	During terminal count per CD 614070, TR-1309, task No. 45, the engine start bottle vent and relief valve, P/N 557818, failed to relieve at the required 1,250 psia. Bottle pressure reached 1,450 psia without any relief indication.	To be determined by Rocketdyne.	The valve was replaced with a like configuration valve and shipped to Rocketdyne for failure analysis and further disposition. This is a GFE item.
1A74039-509 S/N 005	Inverter Electronic Assembly -Chilldown	During voltage and frequency checks of the LH2 chilldown inverter, the inverter failed to operate when turned on. A review of the aft bus No. 2 voltage and current monitor strip chart revealed that at turn-on a 265 amp current spike occurred followed by a 125 amp spike.	Suspected the dummy load (P/N 1B63210-1, S/N 0003) used with this inverter since the same load (S/N 0003) was used when inverter (S/N 0006) failed during pre-test checkout.	The inverter and its associated dummy load were replaced with like configuration items and routed to A-MRCC for further disposition.
1B43657-507 S/N 2004	Module Assembly, Pneumatic Power Control	During propulsion leak check per procedure 1B70176, the pneumatic power control module had a static output pressure of 570 psig. The maximum allowable pressure output for the module is 550 psig.	To be determined.	Module assembly 1B43657-507 modified into 1B43657-511 per dwg chg "M" by reworking module 1A58345-509 into 1A58345-513 per advance E.O. chg. "AB." The redesign of 1B58345 is expected to eliminate excess leakage by implementing a dimensional control of the regulator poppet and seat assembly lapped fit.

1. ENGINE PERFORMANCE PROGRAM (PA49)

This appendix contains the digital printout of computer program PA49. which is a compilation of computer programs AA89, G105, and F823. These computer programs are the methods employed in the propulsion system performance reconstruction of the S-IVB-206 stage acceptance firing. The performance analysis and associated plots are presented in section 6.

Printout symbols are presented in table AP 1-1 and the digital printout is contained in table AP 1-2.

TABLE AP 1-1
PROGRAM PA49 PRINTOUT SYMBOLS

FSUB1	Stage thrust from AA89 (lbf)
WDOTT1	Total flowrate from AA89 (lbm/sec)
WDOTO1	LOX flowrate from AA89 (lbm/sec)
WDOTF1	LH2 flowrate from AA89 (lbm/sec)
EMR 1	Engine mixture ratio from AA89
ISP 1	Specific impulse from AA89 (sec)
MSUBO1	LOX mass onboard from AA89 (lbm)
MSUBF1	LH2 mass onboard from AA89 (lbm)
FSUB2	Stage thrust from G105 (lbf)
WDOTT2	Total flowrate from G105 (lbm/sec)
WDOTO2	LOX flowrate from G105 (lbm/sec)
WDOTF2	LH2 flowrate from G105 (lbm/sec)
EMR 2	Engine mixture ratio from G105
ISP 2	Specific impulse from G105 (sec)
MSUBO2	LOX mass onboard from G105
MSUBF2	LH2 mass onboard from G105 (lbm)
FSUB 3	Stage thrust from F823 (lbf)
WDOTT3	Total flowrate from F823 (lbm/sec)
WDOTO3	LOX flowrate from F823 (lbm/sec)
WDOTF3	LH2 flowrate from F823 (lbm/sec)
EMR 3	Engine mixture from F823
ISP 3	Specific impulse from F823 (sec)
MSUBO3	LOX mass onboard from F823 (lbm)
MSUBF3	LH2 mass onboard from F823 (lbm)
FSUB4	Predicted stage thrust (lbf)
WDOTT4	Predicted total flowrate (lbm/sec)
WDOTO4	Predicted LOX flowrate (lbm/sec)
WDOTF4	Predicted LH2 flowrate (lbm/sec)
EMR 4	Predicted engine mixture ratio
ISP 4	Predicted specific impulse (sec)
MSUBO4	Predicted LOX mass onboard (lbm)
MSUBF4	Predicted LH2 mass onboard (lbm)
THRUST	Composite stage thrust (lbf)
T FLOW	Composite total flowrate (lbm/sec)
O FLOW	Composite LOX flowrate (lbm/sec)
F FLOW	Composite LH2 flowrate (lbm/sec)
EMR	Composite engine mixture ratio
ISP	Composite specific impulse (sec)
O MASS	Composite LOX mass onboard (lbm)
F MASS	Composite LH2 mass onboard (lbm)

TABLE AP 1-2 (Sheet 1 of 4)
ENGINE PERFORMANCE PROGRAM (PA49)

TIME				
FSUB 1	FSUB 2	FSUB P	THRUST	WDOTT1
WDOTT2	WDOTTP	T FLOW	WDOTO1	WDOTO2
WDOTOP	O FLOW	WDOTF1	WDOTF2	WDOTFP
F FLOW	EMR 1	EMR 2	EMR P	*EMR*
ISP 1	ISP 2	ISP P	*ISP*	WSUBO1
WSUBO2	WSUBOP	O MASS	WSUBF1	WSUBF2
WSUBFP	F MASS			
0.000				
50.625	62.755	0.000	56.690	3.527
1.674	0.000	2.600	3.527	0.304
0.000	1.916	0.000	1.370	0.000
0.685	0.000	0.222	0.000	0.111
14.354	37.494	0.000	25.924	193273.000
193273.000	193273.000	193273.000	37046.000	37046.000
36989.000	37046.000			
1.000				
0.000	0.000	0.000	0.000	31.192
4.475	19.937	17.833	13.123	0.773
0.000	6.948	18.069	3.702	19.937
10.985	0.726	0.209	0.000	0.468
0.000	0.000	0.000	0.000	193268.750
193272.783	193273.000	193270.516	37042.425	37044.117
36986.271	37043.271			
2.000				
54444.586	55885.555	94022.165	55165.070	129.588
90.594	206.656	110.091	84.596	64.832
152.027	74.714	44.992	25.761	54.629
35.377	1.880	2.517	2.783	2.198
470.135	616.982	454.968	518.509	193210.494
193250.182	193213.658	193230.338	37000.857	37033.188
36939.922	37017.022			
3.000				
166181.541	166113.900	196892.986	166147.721	361.414
381.975	442.810	371.694	296.526	312.872
363.456	304.699	64.888	69.104	79.354
66.996	4.570	4.528	4.580	4.549
459.810	434.881	444.644	447.346	193028.424
193058.498	192941.139	193043.461	36946.286	36977.392
36873.735	36961.539			
3.100				
172669.686	173311.066	197821.148	172990.275	381.912
398.275	448.756	390.094	314.564	330.478
368.445	322.521	67.348	67.797	80.311
67.573	4.671	4.876	4.588	4.773
452.118	435.154	440.821	443.636	192997.834
193025.416	192904.541	193011.625	36939.646	36970.585
36865.713	36955.116			
3.311				
180549.766	181736.740	196887.180	181143.252	409.457
419.098	454.593	414.278	337.802	350.373
374.062	344.085	71.655	68.725	80.531
70.190	4.714	5.098	4.645	4.906
440.954	433.638	433.107	437.296	192928.613
192952.395	192826.949	192940.504	36924.890	36956.121
36848.642	36940.505			
4.000				
190024.844	190693.416	197837.854	190359.129	438.354
445.554	470.212	441.955	360.854	369.460
389.750	365.157	77.500	76.096	80.461
76.798	4.456	4.855	4.844	4.756
433.496	427.990	420.742	430.743	192685.467
192702.400	192562.682	192693.934	36872.788	36905.301
36792.914	36889.044			
5.000				
194081.973	194304.977	198948.223	194193.424	450.939
456.118	471.534	453.529	371.557	376.943
391.203	374.250	79.382	79.175	80.331
79.278	4.681	4.761	4.970	4.721
430.395	425.987	421.917	428.196	192318.938
192329.881	192171.866	192323.908	36793.787	36827.113
36712.129	36810.450			
6.000				
196214.371	196330.926	200057.561	196272.648	457.690
461.688	472.855	459.689	377.643	381.622
392.654	379.632	80.047	80.066	80.201
80.057	4.718	4.766	4.896	4.742
428.705	425.246	423.085	426.976	191943.729
191948.584	191779.561	191946.156	36713.688	36747.337
36631.476	36730.512			
6.100				
197060.156	197138.697	200168.439	197099.426	458.484
463.857	472.986	461.170	378.385	383.371
392.799	380.878	80.098	80.486	80.188
80.292	4.724	4.763	4.898	4.744
429.808	424.999	423.201	427.404	191905.891
191910.213	191740.250	191908.051	36705.650	36739.258
36623.417	36722.454			
6.300				
197049.336	197196.360	201049.941	197122.839	458.880
463.656	474.970	461.268	378.584	383.449
394.722	381.016	80.296	80.207	80.248
80.251	4.715	4.781	4.919	4.748
429.414	425.308	423.290	427.361	191830.078
191833.447	191661.344	191831.762	36689.540	36723.135
36607.292	36706.337			
7.300				
208771.865	208631.939	205480.297	208701.902	485.525
493.210	484.928	489.368	404.226	410.249
404.377	407.237	81.300	82.961	80.551
82.130	4.972	4.945	5.020	4.959
429.992	423.009	423.734	426.500	191443.084
191439.648	191261.033	191441.365	36608.598	36641.392
36526.496	36624.995			
8.300				
222808.891	222573.113	212198.051	222691.002	521.869
527.866	500.791	524.868	438.671	443.022
419.649	440.846	83.198	84.844	81.142
84.021	5.273	5.222	5.172	5.247
426.944	421.647	423.726	424.295	191015.086
191005.123	190850.201	191010.104	36525.935	36556.669
36445.330	36541.302			
9.300				
224037.818	224124.992	227639.457	224081.404	527.512
531.159	537.209	529.336	443.699	447.266
456.366	445.482	83.913	83.893	82.843
83.853	5.294	5.331	5.509	5.313
424.706	421.955	422.173	423.331	190573.453
190559.035	190409.236	190566.244	36442.018	36472.302
36362.813	36457.160			
10.000				
224915.139	224988.348	228786.346	224951.742	529.101
532.986	541.011	531.044	445.227	449.088
458.227	447.158	83.874	83.899	82.784
83.886	5.308	5.353	5.535	5.331
425.089	422.128	422.887	423.608	190262.326
190245.498	190088.709	190253.912	36383.114	36413.410
36304.964	36398.262			
15.000				
226555.113	226755.543	228746.818	226655.328	535.502
536.992	540.920	536.247	451.899	454.067
458.150	452.983	83.603	82.925	82.769
83.264	5.405	5.476	5.535	5.440
423.070	422.270	422.885	422.670	188014.006
187984.652	187795.705	187999.328	35962.708	35994.226
35888.724	35978.467			
20.000				
227800.539	227923.018	228699.822	227861.777	538.168
539.534	540.830	538.851	455.006	456.830
458.096	455.918	83.162	82.703	82.734
82.933	5.471	5.524	5.537	5.498
423.289	422.445	422.868	422.867	185744.203
185708.611	185503.258	185726.406	35543.868	35577.039
35473.014	35560.453			
25.000				
228599.229	228614.783	228653.504	228607.006	540.187
541.449	540.755	540.818	457.131	458.431
458.067	457.781	83.056	83.018	82.688
83.037	5.504	5.522	5.540	5.513
423.186	422.227	422.841	422.707	183462.947
183427.432	183211.353	183445.189	35126.771	35160.201
35057.531	35143.486			
30.000				
226341.205	226335.525	228626.855	226338.365	539.953
535.432	540.725	537.693	457.212	453.445
458.075	455.329	82.741	81.987	82.650
82.364	5.526	5.531	5.542	5.528
419.187	427.716	422.816	420.951	181176.453
181144.693	180918.934	181160.572	34710.727	34747.033
34642.750	34728.880			
35.000				
227871.840	228003.129	228609.963	227937.484	540.452
539.219	540.720	539.835	457.693	457.312
458.106	457.503	82.759	81.906	82.613
82.333	5.530	5.583	5.545	5.557
421.632	422.840	422.788	422.736	178887.188
178856.961	178626.582	178872.074	34295.127	34333.237
34227.158	34314.182			
40.000				
228657.484	228710.174	228608.984	228683.828	541.168
541.507	540.755	541.337	458.387	458.962
458.177	458.675	82.780	82.545	82.578
82.663	5.537	5.560	5.548	5.549
422.526	422.358	422.759	422.442	176593.797
176565.648	176334.031	176579.723	33879.321	33919.377
33812.242	33899.349			
45.000				
228390.482	228539.914	228688.533	228465.197	540.974
540.624	540.995	540.799	458.155	458.585
458.438	458.370	82.819	82.039	82.557
82.429	5.532	5.590	5.553	5.561
422.184	422.734	422.718	422.459	174294.398
174269.818	174040.586	174282.107	33462.410	33503.438
33397.472	33482.924			
50.000				
228685.809	228827.006	228746.764	228756.406	540.816
541.545	541.174	541.180	457.873	459.176
458.636	458.524	82.943	82.369	82.539
82.656	5.520	5.575	5.557	5.547
422.853	422.545	422.686	422.699	172003.152
171981.457	171746.053	171992.305	33046.542	33090.154
32982.796	33068.348			
55.000				
229371.795	229403.646	228804.994	229387.721	540.870
543.614	541.353	542.242	457.824	460.360
458.833	459.092	83.045	83.254	82.520
83.150	5.513	5.530	5.560	5.521
424.080	421.997	422.654	423.038	169710.279
169686.859	169450.529	169698.568	32630.078	32676.034
32568.217	32653.056			
60.000				
227970.199	228108.410	228863.223	228039.305	540.928
539.850	541.532	540.389	457.856	457.573
459.031	457.715	83.072	82.277	82.502
82.674	5.512	5.561	5.564	5.536
421.443	422.540	422.621	421.992	167418.293
167398.162	167154.023	167408.227	32213.086	32261.838
32153.733	32237.462			

TABLE AP 1-2 (Sheet 2 of 4)
ENGINE PERFORMANCE PROGRAM (PA49)

65.000				
228831.254	228904.453	228811.611	228867.854	540.889
542.195	541.425	541.542	457.765	459.236
458.954	458.490	83.145	82.959	82.471
83.052	5.505	5.536	5.565	5.521
423.065	422.181	422.610	422.623	165125.314
165105.723	164856.911	165115.518	31795.750	31847.685
31739.354	31821.718			
70.000				
228250.180	228431.531	228616.023	228340.855	541.096
540.685	540.943	540.890	457.815	458.279
458.518	458.947	83.280	82.406	82.425
82.843	5.497	5.561	5.563	5.529
421.830	422.486	422.625	422.158	162833.582
162812.686	162581.313	162823.133	31378.054	31430.741
31325.186	31404.398			
75.000				
227472.078	227676.182	228527.266	227624.129	539.618
539.158	540.737	539.388	456.398	456.469
458.345	456.433	83.220	82.690	82.393
82.955	5.484	5.520	5.563	5.502
421.728	422.281	422.621	422.004	160543.463
160521.807	160267.721	160532.635	30959.967	31014.954
30911.231	30987.460			
80.000				
228361.158	228245.387	228577.311	228303.271	539.269
541.093	540.990	540.181	455.977	457.231
458.911	455.604	83.292	83.862	82.379
83.577	5.474	5.452	5.546	5.463
423.464	421.823	422.595	422.644	158258.145
158237.141	157973.774	158247.643	30541.557	30598.348
30497.372	30569.952			
85.000				
227911.760	227834.982	228629.109	227873.371	540.424
540.026	541.944	540.225	456.995	456.459
458.677	456.727	83.428	83.567	82.367
83.498	5.478	5.462	5.569	5.470
421.728	421.896	422.570	421.812	155972.963
155949.404	155674.916	155961.184	30122.852	30179.084
30083.583	30150.969			
90.000				
228202.492	228119.600	228683.734	228161.045	540.461
540.492	541.202	540.526	457.001	456.972
458.863	454.987	83.460	83.620	82.359
83.540	5.476	5.465	5.571	5.470
422.237	421.981	422.548	422.109	153685.834
153661.746	153383.268	153673.539	29703.837	29760.487
29669.839	29732.162			
95.000				
225408.105	225484.070	228560.705	225447.088	538.579
533.555	540.900	536.067	455.054	451.221
458.572	453.137	83.525	82.334	82.328
82.930	5.448	5.480	5.570	5.464
418.424	422.411	422.557	420.567	151399.037
151372.066	151087.648	151385.551	29284.500	29341.687
29256.180	29313.094			
100.000				
226292.785	226368.299	228404.857	226330.541	535.614
535.910	540.514	535.762	452.225	452.961
458.221	452.593	83.389	82.950	82.293
83.170	5.423	5.461	5.568	5.442
422.492	422.399	422.570	422.446	149132.020
149102.785	148793.844	149117.402	28865.725	28923.106
28842.699	28894.415			
105.000				
228034.664	228010.912	228344.463	228022.787	537.887
540.518	540.374	539.203	454.337	456.647
458.103	455.492	83.550	83.871	82.271
83.711	5.438	5.445	5.568	5.441
423.945	421.838	422.567	422.891	146856.189
146824.043	146501.480	146840.115	28445.564	28503.948
28429.375	28474.756			
110.000				
228190.865	228223.754	228404.301	228207.309	540.635
540.837	540.543	540.736	456.758	457.224
458.277	456.991	83.877	83.613	82.266
83.745	5.446	5.468	5.571	5.457
422.079	421.982	422.546	422.031	144580.711
144547.533	144208.682	144564.121	28025.786	28086.186
28016.101	28055.986			
115.000				
226947.135	227029.127	228464.139	226988.131	540.665
537.977	540.712	539.321	456.818	454.861
458.451	455.840	83.847	83.116	82.261
83.482	5.448	5.473	5.573	5.460
419.756	422.005	422.525	420.880	142295.574
142258.137	141915.016	142276.855	27694.250	27667.397
27602.853	27635.823			
120.000				
226796.543	226839.186	228523.977	226817.863	539.619
537.198	540.880	538.409	455.946	454.196
458.625	455.071	83.673	83.002	82.256
83.338	5.449	5.472	5.576	5.461
420.290	422.263	422.504	421.277	140015.660
139976.336	139620.479	139995.998	27183.822	27248.078
27189.432	27214.350			
125.000				
229172.441	229334.277	228403.324	229253.359	540.514
543.596	540.581	542.055	456.566	459.950
458.353	458.259	83.947	83.645	82.228
83.796	5.439	5.499	5.574	5.469
423.990	421.984	422.514	422.937	137732.096
137682.992	137326.053	137707.543	26762.980	26829.269
26776.486	26796.125			

130.000				
227270.904	227311.563	228249.819	227291.232	538.912
538.475	540.197	538.694	455.292	455.220
457.999	455.256	83.620	83.255	82.198
83.438	5.445	5.468	5.572	5.456
421.722	422.139	422.531	421.930	135451.828
135399.443	135033.352	135425.635	26341.858	26408.395
26363.492	26375.126			
135.000				
226853.469	226768.469	228191.434	226810.969	537.628
537.650	540.959	537.639	454.054	453.829
457.880	453.942	83.573	83.820	82.179
83.697	5.433	5.414	5.572	5.424
421.953	421.777	422.531	421.865	133175.563
133122.684	132742.164	133149.123	25921.046	25985.215
25950.439	25953.131			
140.000				
227008.465	227020.441	228252.746	227014.453	536.443
537.953	540.229	537.199	452.955	454.424
458.053	453.689	83.488	83.529	82.176
83.509	5.425	5.440	5.574	5.433
423.173	422.908	422.511	422.591	130903.805
130849.837	130450.498	130876.820	25500.509	25564.693
25537.819	25532.601			
145.000				
225439.875	225336.756	228086.453	225388.314	537.491
533.782	540.138	535.637	453.984	450.553
458.277	452.268	83.597	83.230	81.861
83.368	5.436	5.413	5.598	5.425
419.430	422.151	422.274	420.790	128635.054
128578.231	128157.902	128606.643	25080.020	25143.669
25125.031	25111.844			
150.000				
227092.864	226954.498	228174.256	227023.590	537.069
538.323	540.340	537.696	453.476	454.097
458.445	453.787	83.592	84.226	81.895
83.909	5.425	5.391	5.598	5.408
422.837	421.595	422.279	422.216	126368.232
126310.883	125864.275	126339.558	24659.514	24722.430
24712.181	24690.972			
155.000				
227176.427	227228.506	228109.425	227202.566	538.181
539.238	540.144	538.209	454.548	454.962
458.235	454.755	83.633	83.276	81.910
83.456	5.435	5.463	5.594	5.449
422.119	422.171	422.310	422.145	124093.978
124037.265	123570.614	124065.621	24238.356	24299.546
24299.204	24269.951			
160.000				
226649.184	226581.492	228016.791	226615.338	538.265
537.000	539.982	537.637	454.621	453.397
457.961	454.009	83.644	83.603	81.921
83.623	5.435	5.423	5.590	5.429
421.074	421.960	422.346	421.507	121820.688
121767.784	121278.324	121794.236	23817.392	23878.732
23886.171	23848.061			
165.000				
229274.775	229409.199	227923.270	229341.986	537.513
544.057	539.618	540.785	454.004	460.139
457.688	457.071	83.509	83.918	81.930
83.714	5.437	5.483	5.586	5.460
426.547	421.664	422.379	424.106	119547.493
119498.264	118987.401	119522.878	23396.083	23457.834
23473.084	23426.959			
170.000				
226735.141	226538.949	227905.617	226637.045	537.568
537.444	539.554	537.506	453.641	452.911
457.609	453.276	83.927	84.533	81.945
84.230	5.405	5.358	5.584	5.381
421.779	421.511	422.396	421.645	117274.264
117222.815	116697.565	117248.539	22974.918	23035.998
23059.952	23005.458			
175.000				
225965.777	225928.861	227980.740	225947.318	536.539
535.481	539.729	536.010	452.829	451.870
457.757	452.350	83.710	83.610	81.972
83.660	5.410	5.404	5.584	5.407
421.154	421.918	422.399	421.536	115006.412
114955.795	114407.326	114981.104	22554.019	22613.268
22646.705	22583.643			
180.000				
226415.754	226260.408	228055.863	226338.080	537.217
536.393	539.904	536.805	453.273	452.206
457.906	452.739	83.944	84.188	81.998
84.066	5.400	5.371	5.584	5.386
421.460	421.918	422.401	421.639	112741.217
112689.403	112116.347	112715.310	22133.145	22192.059
22233.323	22162.602			
185.000				
227543.666	227435.918	228353.762	227489.791	535.779
539.695	540.335	537.737	451.880	454.932
458.004	453.406	83.899	84.763	82.330
84.331	5.386	5.367	5.563	5.377
424.697	421.416	422.616	423.056	110478.955
110423.114	109824.698	110451.034	21712.575	21770.539
21819.800	21741.557			
190.000				
226108.844	225973.984	228330.779	226041.414	534.500
535.844	540.291	535.172	450.890	451.653
457.979	451.272	83.610	84.191	82.312
83.900	5.393	5.365	5.564	5.379
423.029	421.716	422.607	422.372	108219.408
108163.772	107532.695	108191.590	21292.122	21348.240
21406.253	21320.181			

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ENGINE PERFORMANCE PROGRAM (PA49)

195.000				
226405.469	226384.988	228224.422	226395.229	533.853
536.641	540.033	535.247	450.270	452.706
457.749	451.488	83.583	83.935	82.283
83.759	5.387	5.394	5.563	5.390
424.097	421.956	422.612	422.977	105963.415
105905.474	105241.573	105934.444	20872.152	20927.002
20992.834	20899.577			
200.000				
226803.346	226794.070	228118.066	226778.707	535.849
537.486	539.775	536.668	452.139	453.526
457.520	452.832	83.711	83.960	82.255
83.835	5.401	5.402	5.562	5.401
423.260	421.879	422.617	422.569	103706.471
103643.748	102951.597	103674.109	20452.061	20505.557
20579.559	20479.809			
205.000				
227580.096	227497.934	228011.662	227539.014	536.382
539.589	539.516	537.985	452.714	455.265
457.298	453.989	83.668	84.324	82.227
83.996	5.411	5.399	5.561	5.405
424.287	421.614	422.622	422.950	101439.986
101378.134	100662.769	101409.010	20031.608	20084.543
20166.426	20058.375			
210.000				
225997.100	225903.420	227973.270	225950.260	536.100
535.423	539.434	535.762	452.462	451.664
457.227	452.063	83.639	83.759	82.207
83.699	5.410	5.392	5.562	5.401
421.557	421.916	422.616	421.737	99176.576
99112.263	98376.908	99144.409	19611.542	19662.263
19753.425	19636.902			
215.000				
227284.291	227609.920	228019.459	227347.055	537.071
538.938	539.546	538.005	453.144	455.342
457.368	454.243	83.928	83.596	82.198
83.762	5.399	5.447	5.584	5.423
423.192	421.959	422.597	422.575	96911.715
96844.529	96086.652	96878.122	19191.439	19241.484
19340.482	19216.462			
220.000				
226731.020	226509.881	228047.648	226619.949	533.565
537.275	539.658	535.420	450.168	452.652
457.479	451.410	83.397	84.623	82.188
84.010	5.398	5.349	5.566	5.373
424.936	421.589	422.578	423.262	94644.285
94576.675	93797.790	94610.479	18770.428	18819.581
18927.587	18795.904			
225.000				
225208.354	225081.347	228085.057	225144.948	534.479
533.599	539.770	534.036	450.908	449.757
457.891	459.333	83.569	83.832	82.179
83.701	5.396	5.365	5.568	5.380
421.362	421.825	422.560	421.593	92388.393
92317.064	91508.316	92352.729	18351.077	18396.883
18514.740	18373.980			
230.000				
225439.514	225351.439	228122.822	225395.477	533.416
534.175	539.883	533.795	449.931	450.339
457.713	453.135	83.485	83.835	82.170
83.660	5.389	5.372	5.570	5.381
422.634	421.868	422.541	422.251	90135.579
90065.198	89219.233	90100.389	17932.187	17976.796
18101.939	17954.491			
235.000				
225637.029	225604.605	228054.668	225620.816	533.333
534.653	539.721	533.993	449.918	451.002
457.574	450.460	83.415	83.651	82.147
83.533	5.396	5.391	5.570	5.393
423.070	421.945	422.542	422.517	87884.016
87817.097	86924.148	87848.056	17513.218	17556.860
17689.713	17535.039			
240.000				
224407.758	224364.903	227973.939	224386.279	532.157
531.121	539.528	531.639	449.213	448.297
457.404	448.755	82.944	82.824	82.123
82.884	5.416	5.413	5.570	5.414
421.695	422.436	422.543	422.065	85633.454
85540.910	84639.896	85596.981	17094.579	17137.089
17276.606	17115.834			
245.000				
224299.203	224158.339	227893.029	224228.779	532.622
530.975	539.333	531.799	449.557	447.717
457.234	448.637	83.065	83.259	82.100
83.162	5.412	5.377	5.569	5.395
421.123	422.163	422.546	421.643	83384.206
83314.132	82350.493	83349.169	16676.240	16718.195
16864.119	16697.217			
250.000				
226940.617	226804.338	227811.836	226872.477	537.451
537.656	539.137	537.553	454.195	453.927
457.060	454.061	83.256	83.729	82.077
83.493	5.455	5.421	5.569	5.438
422.254	421.839	422.549	422.046	81133.989
81065.773	80062.953	81099.881	16259.064	16296.301
16451.747	16277.182			
255.000				
226481.275	226275.807	227730.643	226378.541	532.382
536.663	538.941	534.522	449.389	452.354
456.987	450.971	82.996	84.308	82.055
83.651	5.415	5.365	5.568	5.390
425.411	421.635	422.552	423.523	78872.563
78803.832	77774.280	78838.197	15838.898	15874.919
16039.490	15856.909			
260.000				
225170.260	225010.545	227703.676	225090.402	534.247
533.087	538.486	533.667	451.199	449.702
456.847	450.451	83.048	83.384	82.039
83.216	5.433	5.393	5.569	5.413
421.472	422.090	422.545	421.781	76616.503
76548.271	75490.357	76582.387	15420.510	15454.431
15627.340	15437.470			
265.000				
225726.221	225718.219	227733.361	225722.219	534.674
534.483	538.976	534.579	451.611	451.529
456.946	451.570	83.062	82.954	82.031
83.008	5.437	5.443	5.570	5.440
422.176	422.311	422.530	422.244	74356.663
74289.646	73204.043	74323.154	15001.899	15033.590
15215.238	15017.745			
270.000				
225694.867	225553.949	227759.701	225624.408	534.211
534.273	539.058	534.242	451.095	450.791
457.036	459.943	83.115	83.482	82.022
83.299	5.427	5.400	5.572	5.414
422.483	422.170	422.514	422.326	72097.863
72033.030	70917.270	72065.446	14583.431	14612.259
14803.180	14597.845			
275.000				
225421.705	225361.068	227786.041	225391.387	534.447
533.645	539.140	534.046	451.288	450.530
457.127	450.909	83.159	83.115	82.013
83.137	5.427	5.421	5.574	5.424
421.785	422.305	422.499	422.045	69839.608
69777.189	68630.042	69808.398	14164.761	14191.381
14391.167	14178.071			
280.000				
224970.506	224868.896	227812.381	224919.701	532.734
532.351	539.221	532.543	449.927	449.377
457.218	449.652	82.807	82.974	82.004
82.890	5.433	5.416	5.576	5.425
422.294	422.407	422.484	422.351	67585.491
67524.686	66342.362	67555.088	13746.664	13772.169
13979.200	13759.407			
285.000				
224706.193	224766.133	227717.094	224736.162	531.513
532.005	538.985	531.759	448.657	449.405
457.004	449.031	82.856	82.600	81.981
82.728	5.415	5.441	5.575	5.428
422.767	422.489	422.492	422.628	65337.809
65275.464	64054.750	65306.636	13328.979	13354.377
13567.301	13341.678			
290.000				
225192.146	225161.393	227564.189	225176.770	532.355
533.177	538.597	532.746	449.374	450.103
456.642	449.739	82.980	83.074	81.955
83.027	5.415	5.418	5.572	5.417
423.012	422.301	422.513	422.656	63089.661
63027.470	61768.852	63058.565	12911.190	12936.917
13155.534	12924.053			
295.000				
224526.652	224364.609	221146.094	224445.631	531.914
531.525	522.371	531.720	449.020	448.169
441.475	448.595	82.894	83.356	80.846
83.125	5.417	5.377	5.461	5.397
422.111	422.115	423.391	422.113	60842.771
60784.041	59503.497	60813.406	12493.573	12517.073
12744.886	12505.323			
300.000				
224758.721	224617.998	208806.764	224688.359	531.169
532.301	490.907	531.735	448.033	448.581
412.088	448.307	83.136	83.719	78.820
83.428	5.389	5.358	5.228	5.374
423.140	421.976	425.349	422.558	58595.157
58541.443	57370.778	58568.300	12075.831	12097.250
12341.152	12086.541			
305.000				
224331.313	224180.887	200682.061	224256.100	531.378
530.496	469.902	530.937	449.004	447.848
392.135	448.426	82.374	82.649	77.767
82.511	5.451	5.419	5.042	5.435
422.169	422.587	427.072	422.378	56347.626
56299.754	55366.743	56323.690	11658.338	11675.577
11944.060	11664.958			
310.000				
223408.547	223219.113	196298.906	223313.830	531.202
528.293	458.516	529.747	448.940	445.798
381.769	447.369	82.262	82.495	77.247
82.378	5.457	5.406	4.936	5.431
420.572	422.529	428.118	421.550	54101.129
54061.688	53434.765	54081.408	11241.136	11254.989
11550.493	11248.062			
315.000				
223716.396	223467.506	194435.717	223591.951	531.019
529.204	453.650	530.111	448.520	446.115
376.601	447.318	82.499	83.089	77.049
82.794	5.437	5.369	4.888	5.403
421.296	422.271	428.603	421.784	51855.991
51824.693	51538.522	51840.342	10823.893	10834.790
11158.558	10829.341			
320.000				
223294.791	223110.619	193024.301	223202.705	531.505
527.854	449.954	529.679	449.216	445.504
373.044	447.360	82.289	82.350	76.909
82.320	5.459	5.410	4.850	5.434
420.118	422.675	428.987	421.396	49610.528
49585.271	49662.841	49597.899	10406.392	10412.399
10767.469	10409.396			

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325.000				
223944.965	223896.895	192049.244	223920.930	531.102
529.528	447.384	530.315	448.700	447.342
370.558	448.721	82.402	82.186	76.826
82.296	5.445	5.443	4.823	5.444
421.661	422.823	429.271	422.242	47363.231
47346.541	47803.328	47354.886	9998.403	9991.191
10377.001	9989.797			
330.000				
224749.896	224394.795	191588.207	224572.346	531.444
531.754	446.142	531.599	449.057	448.074
369.330	448.565	82.387	83.680	76.812
83.034	5.451	5.355	4.808	5.403
422.904	421.990	429.436	422.447	45119.643
45112.346	45951.868	45115.994	9571.057	9572.309
9986.785	9571.683			
335.000				
223916.516	223737.787	191436.770	223827.150	531.060
529.477	445.700	530.268	448.663	446.798
368.863	447.731	82.396	82.680	76.836
82.538	5.445	5.404	4.901	5.425
421.641	422.564	429.520	422.102	42876.965
42880.012	44105.405	42878.488	9153.890	9152.138
9596.676	9153.009			
340.000				
223197.801	222943.330	191569.436	223070.564	532.236
527.536	445.993	529.886	449.913	445.053
369.095	447.483	82.324	82.483	76.897
82.403	5.465	5.396	4.800	5.430
419.358	422.413	429.535	420.986	40628.211
40634.936	42258.995	40631.573	8735.986	8728.271
9204.416	8732.128			
345.000				
225722.156	225415.555	191944.504	225568.855	531.469
534.213	444.919	532.841	449.149	450.452
369.935	449.801	82.320	83.761	76.984
83.041	5.456	5.378	4.805	5.417
424.714	421.958	429.483	423.336	38378.652
38392.383	40409.380	38385.518	8318.194	8306.580
8815.842	8312.387			
346.000				
223466.168	223217.838	192004.516	223342.002	531.337
528.716	447.068	529.777	448.936	445.509
370.070	447.722	82.407	82.707	76.998
82.554	5.448	5.397	4.806	5.417
420.573	422.598	429.475	421.591	37928.756
37944.809	40039.010	37936.782	8234.643	8222.106
8737.692	8229.375			
347.000				
224767.451	224508.098	192064.525	224637.773	531.880
531.684	447.216	531.782	449.394	448.408
370.704	449.001	82.496	83.276	77.012
82.881	5.448	5.385	4.807	5.416
422.590	422.259	429.467	422.425	37479.212
37498.082	39668.508	37488.647	8151.104	8138.237
8659.532	8144.671			
348.000				
226606.448	226157.174	192124.537	226381.910	531.601
536.567	447.365	534.084	449.129	451.800
370.339	450.464	82.473	84.767	77.026
83.620	5.446	5.330	4.808	5.388
426.272	421.689	429.459	423.881	37029.273
37048.010	39297.867	37038.647	8067.456	8053.645
8581.361	8060.551			
348.500				
223888.131	223500.709	192154.543	223694.420	532.708
529.903	447.639	531.105	450.175	446.075
370.406	448.125	82.533	83.429	77.033
82.981	5.454	5.347	4.808	5.401
420.283	422.995	429.456	421.189	36804.247
36822.787	39117.497	36813.517	8025.634	8010.941
8542.273	8018.287			
349.000				
223938.354	223772.188	192184.549	223855.271	532.364
529.357	447.513	530.861	449.917	446.925
370.473	448.421	82.448	82.432	77.040
82.440	5.457	5.422	4.809	5.439
420.669	422.724	429.450	421.687	36579.065
36599.199	38927.094	36589.122	7983.819	7968.848
8503.181	7976.333			
350.000				
224848.920	224597.680	192244.559	224723.199	532.389
531.882	447.661	532.136	449.909	448.685
370.408	449.297	82.480	83.197	77.053
82.839	5.455	5.393	4.810	5.424
422.339	422.769	429.442	422.304	36128.705
36150.441	38556.186	36139.573	7900.191	7884.588
8424.990	7892.389			
355.000				
223798.076	223645.787	192585.752	223721.932	532.718
529.214	448.517	530.966	450.208	446.759
371.396	449.483	82.510	82.456	77.121
82.483	5.456	5.418	4.816	5.437
420.106	422.600	429.383	421.353	33878.073
33904.984	36699.517	33892.029	7481.904	7463.224
8033.878	7472.564			
360.000				
223185.094	222958.234	192825.922	223071.664	530.661
527.628	449.124	529.144	448.704	444.923
371.959	446.564	82.456	82.705	77.165
82.581	5.436	5.380	4.820	5.408
420.580	422.567	429.337	421.573	31630.842
31666.352	34838.663	31648.597	7063.928	7042.618
7642.476	7053.273			
365.000				
224412.074	224231.400	192789.961	224321.836	530.290
530.815	449.019	530.552	447.950	447.862
371.846	447.906	82.339	82.952	77.172
82.646	5.440	5.399	4.818	5.420
423.188	422.429	429.358	422.808	29389.534
29430.137	32977.352	29409.835	6646.410	6621.930
7250.977	6634.170			
370.000				
222920.100	222697.588	192138.455	222808.844	526.292
527.241	447.323	526.766	444.106	444.192
370.225	444.149	82.186	83.048	77.098
82.617	5.404	5.349	4.802	5.376
423.567	422.383	429.529	422.975	27154.915
27199.729	31120.637	27177.322	6229.460	6203.311
6859.663	6216.385			
375.000				
219111.387	218919.762	191599.154	219015.574	521.181
517.637	445.918	519.409	438.960	435.294
368.880	437.077	82.321	82.343	77.038
82.332	5.331	5.286	4.788	5.309
420.413	422.921	429.673	421.667	24951.186
25003.150	29271.145	24977.168	5813.155	5783.285
6468.675	5798.220			
380.000				
212216.871	212136.600	191059.967	212176.734	499.989
501.125	444.513	500.557	418.457	419.217
367.535	418.837	81.532	81.908	76.978
81.720	5.132	5.118	4.775	5.125
424.443	423.321	429.819	423.882	22858.170
22864.967	27429.378	22836.568	5397.756	5366.216
6077.988	5381.986			
385.000				
204626.816	204635.480	190728.773	204631.148	485.047
481.916	443.647	483.482	404.209	401.748
366.704	402.979	80.838	80.168	76.944
80.503	5.000	5.011	4.766	5.006
421.870	424.429	429.911	423.249	20745.497
20807.867	25591.301	20776.682	4986.133	4954.628
5687.548	4970.380			
390.000				
200668.926	200639.531	190470.727	200653.729	470.853
472.164	442.972	471.508	391.023	392.118
366.054	391.571	79.830	80.046	76.918
79.938	4.998	4.999	4.759	4.898
426.182	424.934	429.986	425.558	18762.259
18822.826	23757.717	18792.542	4580.335	4550.215
5297.248	4565.275			
395.000				
195576.057	195811.648	190244.199	195693.852	459.388
459.082	442.378	459.235	380.497	381.310
365.482	380.904	78.891	77.772	76.896
78.332	4.823	4.903	4.753	4.863
425.732	426.528	430.049	426.130	16832.330
16890.875	21927.110	16861.603	4178.781	4149.595
4907.063	4164.188			
400.000				
193703.234	193672.258	190120.865	193687.746	455.062
454.110	442.051	454.586	376.691	375.928
365.164	374.309	78.371	78.182	76.887
78.277	4.907	4.809	4.749	4.807
425.663	426.488	430.088	426.076	14936.827
14991.939	20098.981	14964.383	3789.697	3751.124
4516.967	3765.910			
405.000				
193825.055	193997.035	190175.115	193911.045	453.374
454.743	442.189	454.058	374.995	376.911
365.293	375.953	78.379	77.832	76.897
78.106	4.784	4.843	4.750	4.813
427.517	426.609	430.076	427.063	13051.108
13098.127	18271.446	13074.618	3383.405	3356.073
4126.868	3369.739			
410.000				
193298.289	193322.953	190397.195	193310.621	454.391
452.992	442.770	453.692	376.099	375.198
365.850	375.648	78.292	77.795	76.920
78.043	4.904	4.823	4.756	4.813
425.401	426.769	430.013	426.085	11170.659
11211.592	16441.765	11191.120	2984.692	2961.068
3736.674	2973.880			
415.000				
193155.949	193259.436	190619.275	193207.691	451.939
452.712	443.351	452.326	373.850	375.076
366.408	374.463	78.089	77.636	76.943
77.863	4.787	4.831	4.762	4.809
427.394	426.893	429.951	427.143	9292.227
9326.371	14609.297	9309.299	2590.252	2565.458
3346.365	2577.855			
420.000				
193672.408	193889.238	190841.359	193781.322	450.353
454.114	443.932	452.234	372.411	376.593
366.966	374.502	77.942	77.521	76.966
77.731	4.778	4.858	4.768	4.818
430.046	426.964	429.888	428.505	7426.054
7454.805	12774.040	7440.429	2195.143	2174.028
2955.940	2184.586			
425.000				
191558.340	191716.996	190777.518	191637.668	449.868
448.748	443.778	449.308	372.005	371.788
366.830	371.896	77.843	76.960	76.948
77.411	4.778	4.831	4.767	4.804
425.810	427.226	429.894	426.518	5559.191
5581.629	10937.709	5570.410	1800.180	1784.129
2565.494	1792.154			
430.000				
193017.406	193205.824	190039.494	193111.615	452.037
452.849	441.988	452.443	373.627	375.126
365.051	374.377	78.410	77.723	76.937
78.066	4.765	4.826	4.751	4.796
426.994	426.646	430.062	426.820	3694.088
3713.664	9106.220	3703.876	1404.843	1388.637
2175.383	1396.740			
435.000				
193210.551	193212.900	189288.143	193211.725	452.730
452.832	439.963	452.781	374.856	375.060
363.240	374.958	77.874	77.772	76.723
77.823	4.814	4.823	4.734	4.818
426.767	426.677	430.236	426.722	1819.588
1831.041	7283.791	1825.315	1008.160	995.326
1789.838	1001.743			
436.000				
192107.742	192151.725	189137.873	192129.732	449.969
449.571	439.978	449.770	372.957	372.927
362.877	372.942	77.012	76.644	76.701
76.828	4.843	4.866	4.731	4.854
426.935	427.411	430.271	427.173	1444.994
1455.938	6920.392	1450.466	929.622	917.047
1707.997	923.334			
436.150				
193052.451	193054.145	189115.332	193053.297	449.908
451.925	439.520	450.916	373.249	375.044
362.923	374.166	76.660	76.881	76.697
76.770	4.869	4.878	4.731	4.874
429.093	427.182	430.277	428.138	1388.982
1399.992	6865.911	1394.487	917.940	905.420
1696.322	911.680			

TABLE AP 2-1 (Sheet 1 of 2)
ABBREVIATIONS

ITEM	TERM	ITEM	TERM
ac	Alternating current	He	Helium
Act	Actuator	hr	Hour
APS	Auxiliary Propulsion System	Hyd	Hydraulic
Attch	Attach	in.	Inch
Btu	British thermal unit	IP&CL	Instrumentation Program and Component List
Cfm	Cubic feet per minute	IU	Instrumentation unit
Contr	Control	K	Kilo = 1,000 or 10^3
cps	Cycles per second	kc	Kilocycle
DAC	Douglas Aircraft Company, Inc.	KSC	Kennedy Space Center
db	Decibel	lbf	Pounds force
dc	Direct current	lbm	Pounds mass
DDAS	Digital Data Acquisition System	LH2	Liquid hydrogen
Disch	Discharge	Loc	Location
DPF	Differential Pressure Feedback	LOX	Liquid oxygen
EBW	Exploding Bridgewire	ms	Millisecond
ECC	Engine Cutoff Command	MSFC	Marshall Space Flight Center
E/I	External/Internal	NASA	National Aeronautics and Space Administration
EMI	Electromagnetic Interference	NPSH	Net positive suction head
EMR	Engine mixture ratio	PAM	Pulse amplitude modulation
ESC	Engine Start Command	PCM	Pulse code modulation
FLT	Flight	pf	Picofarad
ft	Feet	Posit	Position
FM	Frequency modulation	pps	Pulses per second
FTC	Florida Test Center	Press	Pressure
Fwd	Forward	psia	Pounds per square inch, absolute
GG	Gas generator	psid	Pounds per square inch, differential
GH2	Gaseous hydrogen	psig	Pounds per square inch, gauge
GN2	Gaseous nitrogen	Pt	Point
gpm	Gallons per minute		
GSE	Ground support equipment		

TABLE AP 2-1 (Sheet 2 of 2)
ABBREVIATIONS

ITEM	TERM	ITEM	TERM
PU	Propellant utilization	sw	Switch
Pwr	Power	Syst	System
R	Rankine	TAN	Tangential
RAD	Radial	Temp	Temperature
Refl	Reflected	T/M	Telemetry
Reg	Regulator	TP&E	Test Planning and Evaluation
RF	Radio frequency	TRW	Thompson-Ramo-Wooldridge
RMR	Reference mixture ratio	Vac	Volts alternating current (100 vac)
RSS	Root sum square		
SCI	Standard cubic inch	V	Volts
scim	Standard cubic inch per minute	Vib	Vibration
scfm	Standard cubic foot per minute	vdc	volts direct current
sec	Second	W	Watts
STC	Sacramento Test Center		

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KN00	Deputy Chief Design Engineer - Saturn Development
KA00	Chief Engineer - Mechanics & Reliability
KAF0	Branch Chief - S-IVB Mechanics & Reliability
KABA	Section Chief - Strength
KABC	Section Chief - Acoustics & Structural Dynamics
KACA	Section Chief - Flight Dynamics & Control
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KCBC	Propulsion Performance and TP&E - Analysis
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KCD0	Branch Chief - Propulsion Test
KCDE	Propulsion Test
KD00	Chief Engineer - Electronics
KDBA	Section Chief - Test Planning & Evaluation
KDC0	Branch Chief - Electronics S-IVB Stage Design
KDCA	Section Chief - Networks & Subsystem Design
KDF0	Branch Chief - Data Systems
KEC0	Branch Chief - Computing Engineering
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KK00	Chief Project Engineer - Saturn Development
KKB0	Project Engineer - Test
KKB0	Deputy Project Engineer - Test
KKBA	Assistant Project Engineer - TP&E
KKBA	Supervisor - S-IVB Static Test
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AFD3	Materials Research/Production Methods
KABA	Strength
KABB	Weight Control
KABC	Acoustics & Structural Dynamics

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